PHYSICAL CHARACTERISTICS OF THE HUMBER RIVER

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TECHNICAL REPORT # 3

A REPORT
OF THE

TORONTO AREA WATERSHED
MANAGEMENT STRATEGY
STEERING COMMITTEE

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Environment Canada

PHYSICAL CHARACTERISTICS

OF

THE HUMBER RIVER

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TORONTO AREA WATERSHED

MANAGEMENT STRATEGY

STEERING COMMITTEE

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Abstract

As part of the Toronto Area Watershed Management Strategy Study, the Metropolitan Toronto and Region Conservation Authority and the Water Resources Branch of the Ministry of the Environment carried out a physical survey of the Humber River during the summer of 1983. The study area was confined to the portion of the Humber River watershed within the boundaries of Metropolitan Toronto, starting at Steeles Avenue and ending at the mouth of the river.

Data from this survey are to be used in the analysis of sediment transport and other computer modelling studies. This report also presents the results of a previous survey carried out in the fall of 1982 during which time of travel was measured. Standard methods for measuring channel geometry, sediment deposition, time of travel and streamflow were used.

Results indicate that average stream depth ranged from 0.14 m to 2.11 m, and stream width varied from 12 m to 85 m. Time of travel ranged from 0.50 hours to 6.83 hours throughout the study period depending on the reach and flow. Reach lengths ranged from 2930 m to 12010 m. Bed slope ranged from 0.05% near Lake Ontario to 0.40% upstream of Bloor Street and 0.06% upstream of Highway 401. In general, the spatial distribution of the sediment deposits reflects the hydraulic characteristics of the river. The depth of sediment accumulation ranged from 1.5 m to 2.0 m near Lake Ontario to occasional patches near Steeles Avenue. The relatively small volume of deposited sediment indicates that the majority of sediment produced by the Humber River watershed is transported into Lake Ontario.

Acknowledgements

The authors would like to thank Dr. I. Heathcote, Messrs. D.G. Weatherbe, Z. Novak and B. Whitehead of the Ministry of Environment and Mr. B. Hindley of the Metropolitan Toronto and Region Conservation Authority for editing and constructive criticism in reviewing this report.

1. Introduction

In 1981 the Ministry of the Environment initiated a five-year project, the Toronto Area Watershed Management Strategy Study (TAWMS), to investigate areas of Metropolitan Toronto river systems where there is a need for water quality improvement, and to develop cost-effective measures for achieving those improvements.

One of the tasks within the TAWMS study is to evaluate sediment transport mechanisms and related contaminant movement in the Don and Humber Rivers. As part of that task the Metropolitan Toronto and Region Conservation Authority (MTRCA) and the Water Resources Branch of the Ministry of the Environment jointly undertook a physical survey of the Humber River during the months of July to October 1983. The physical survey included establishment of the river profile, channel geometry, and the mapping of zones of sediment depositon.

This report presents the results of the physical survey along with data from a time of travel survey conducted in 1982 by the Ministry of the Environment, and forms the foundation of subsequent analyses of sediment transport and related studies.

2. Description of River Basin

The following description of the Humber River basin (see Figure 1) has been taken from the October 1979 report, "Hydrologic Model Study Humber, Don, and Rouge Rivers, Highland, Duffin, Petticoat and Carruther's Creeks", published by James F.MacLaren Limited:

"The Humber River drainage area of 857 square kilometres is the largest watershed under the jurisdiction of the MTRCA encompassing about one third of the total area within the Authority. The basin is bounded on the east by the Don River and the west by the Mimico and Etobicoke Creeks. Located within the Regional municipalities of Peel, York and Metropolitan Toronto, parts of the watershed lie within the individual municipalities of Caledon, Brampton, Mississauga, King, Vaughan, North York, Etobicoke and the City of Toronto.

The West branch of the Humber River drains approximately 200 sq. km of the Peel Plain before joining the main Branch at Thistletown. The combination of dense dendritic drainage pattern, a quite steep stream gradient of 0.46 percent and impervious soils of the clay plain gives rise to high flow rates during precipitation and snowmelt events. In view of this flood potential, the Claireville Dam was constructed on this branch of the river as part of the Authority's 1959 Plan for flood control.

The main branch of the Humber River rises in the moraine hills about seven kilometres east of Orangeville and flows in a southeasterly direction to Lake Ontario falling approximately 400 metres in a distance of 90 kilometres. Average stream gradients are greater than 1 percent in the upper areas declining to about 0.25 percent south of Cedar Mills. Drainage paths in the upstream areas are not well defined with many depressed areas having no apparent connection to the main stream. The generally sandy soils found in the upstream areas

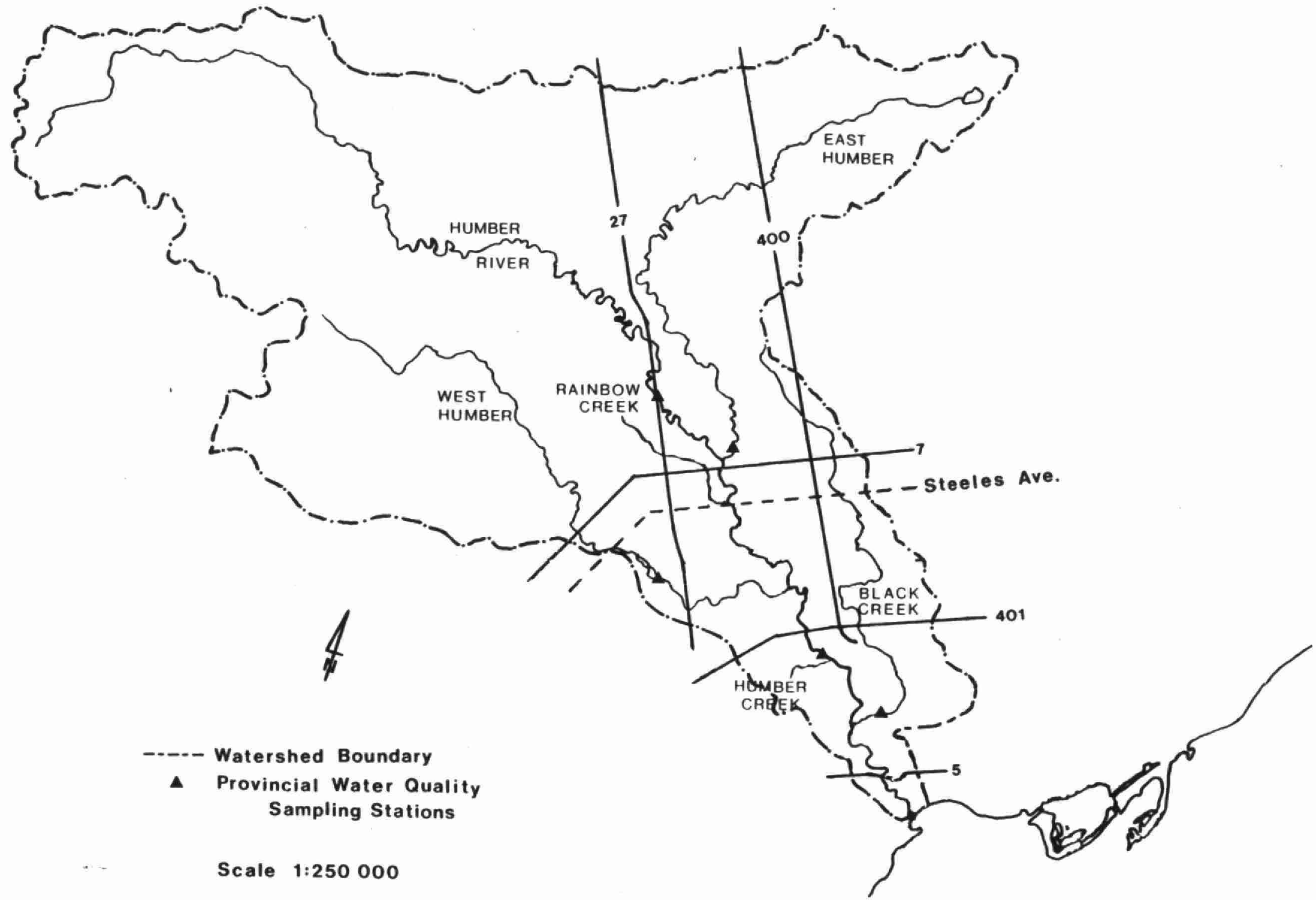

Figure 1 Humber River Watershed

also reduce the runoff response of the watershed resulting in comparatively low peak annual flows. Many small impoundments located on the stream and the wooded area upstream of Cedar Mills which covers 20 to 30 percent of the upper watershed compound this effect.

The east branch of the Humber River rises in Lake Wilcox just east of Yonge Street in the village of Oak Ridges. Topography is generally similar to that found in the upstream areas of the main branch. A lower proportion of the area is covered by pervious soils. The stream falls at a gradient of about 4 percent before joining the main branch at Woodbridge with a drainage area of 190 sq. km. Most noticeably, the waterway has cut a narrow deep valley with steep sides which are subject to considerable undercutting at times of flooding.

In general the basin is predominantly rural with major concentrations of urban activity in the southern part of the watershed to the south of Steeles Avenue. Black Creek is the most densely urbanized tributary of the basin."

For the purposes of this survey, only the portion of the main branch of the Humber River within the boundaries of Metropolitan Toronto, a distance of 26.2 km stretching from Steeles Avenue to the mouth, was considered. The division of land use activities within this area along the Humber River watershed is as follows: residential (47%), industrial (20%) and open areas (33%). The tributaries as well as the main branch of the Humber River contain a number of man-made structures (weirs, bank stabilization structures and concrete lined sections) which were constructed for erosion control, but which also affect the flow characteristics in this area.

3. Methods

Standard methods for measuring channel geometry, sediment deposition, time of travel and streamflow were used. Details of the various methodologies employed are presented in Table 1.

The river profile and channel geometry were established by taking cross-sections at selected sites along the Humber River and then surveying to those sites from known bench mark elevations to obtain geodetic elevations at each site. Preliminary field investigations indicated that the reach of the Humber River downstream of Bloor Street was likely to be an area containing major sediment deposits. For this reason, a greater number of cross-sections were taken within this reach than were taken in other stretches of the river. Figures 2 and 3 show the locations of the cross-sections surveyed within the study area.

Sediment mapping was also sub-divided into two regions as outlined above (Steeles-Bloor and Bloor-mouth). For the reach of the Humber River from Bloor Street to the mouth, sediment depths were measured at the 20 locations where cross-sections were surveyed. In the stretch of river between Steeles Avenue and Bloor Street, pockets of sediment were located, then the lateral and longitudinal extents of the pockets were measured and plotted on topographical maps.

The time of travel data was obtained from a survey conducted in 1982 by the Water Resources Branch of the Ministry of the Environment. Figure 4 shows the river sampling stations utilized in the time of travel study.

Table 1: Details of Methods

Parameter	Dates Performed	Stations	Methods
1. Channel Geometry and River Profile	Sept. 27/83 - Oct. 7/83	20 cross-sections between the mouth of the Humber River and Bloor Street (see Figure 2).	Geodetic elevations were obtained by employing standard surveying (levelling) techniques. Longitudinal distances were measured from 1:2000 scale topographical maps supplied by MTRCA. A graduated rod and surveying chain were used to measure depths and widths. Cross-section intervals were determined by changes in the river morphology.
	July 11-19/83	16 cross-sections from Bloor Street to Highway 27, (see Figure 3).	
2. Sediment Mapping	July 26-28/83	Same 20 cross-sections surveyed for channel geometry between the mouth of the Humber River and Bloor Street (see Figure 2).	Sediment depths were measured using a graduated rod. Depth was determined by locating the upper limit of the sediment with the rod and then measuring the depth by which the rod penetrated the sediment when forced downwards. The water surface was used as a zero indicator from which all depths were measured. All measuremnets were made by wading, except in the deeper sections where a canoe was used
	Aug. 3-10/83	Upstream of Bloor Street to Steeles Avenue along the main branch of the Humber River.	

Table 1: Details of Methods (cont'd)

Parameter	Dates Performed	Stations	Methods
3. Time of Travel	Oct. 14/82 - Dec. 2/82	Stations 10-9, 9-7, 7-6, 6-3, along the main Humber River and 11-5 on Black Creek (see Figure 4).	A slug of Rhodamine-WT dye (100-500 mL, depending on the flow) was dumped at the head of each reach. Automatic samplers were then used at the end of each reach to collect water samples. Samplers were preset to start sampling at approximately one hour before the estimated time of travel. Samples were then analyzed for fluorescence (related to dye concentration). The difference between the time the dye was dumped and the time of the peak concentration of the dye cloud is taken as the time of travel for the reach. Streamflow was also measured at staff and recording gauges to relate the time of travel to the streamflow.

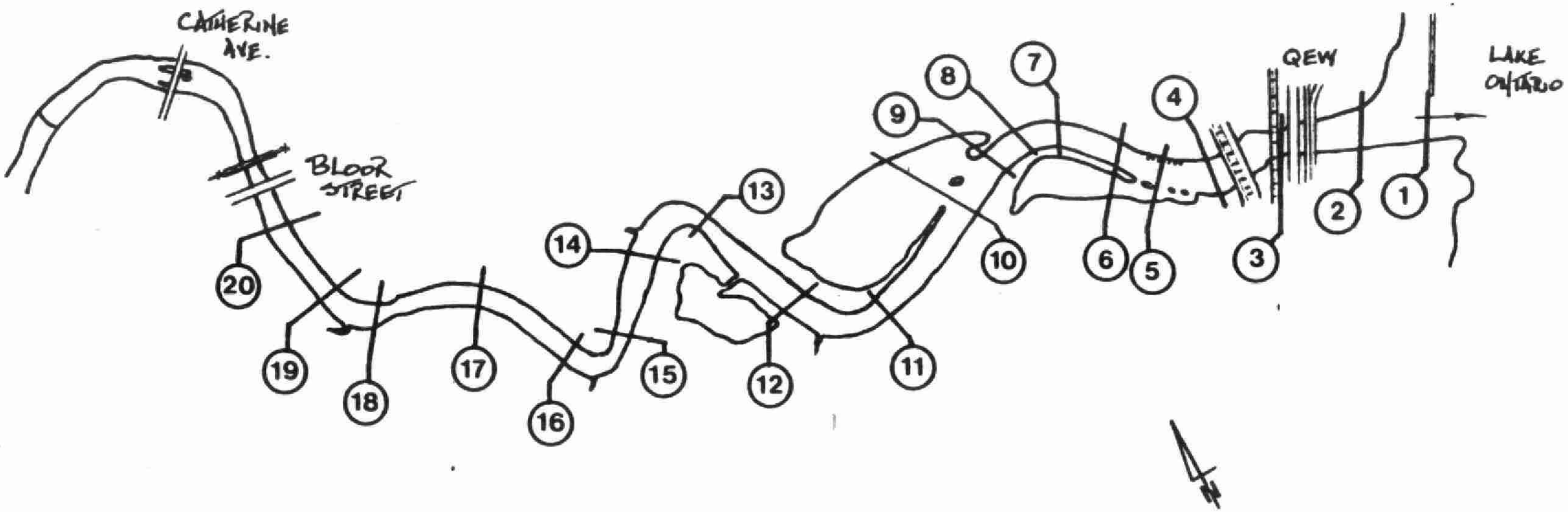

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Figure 2 Cross-section Locations - Downstream of Bloor Street

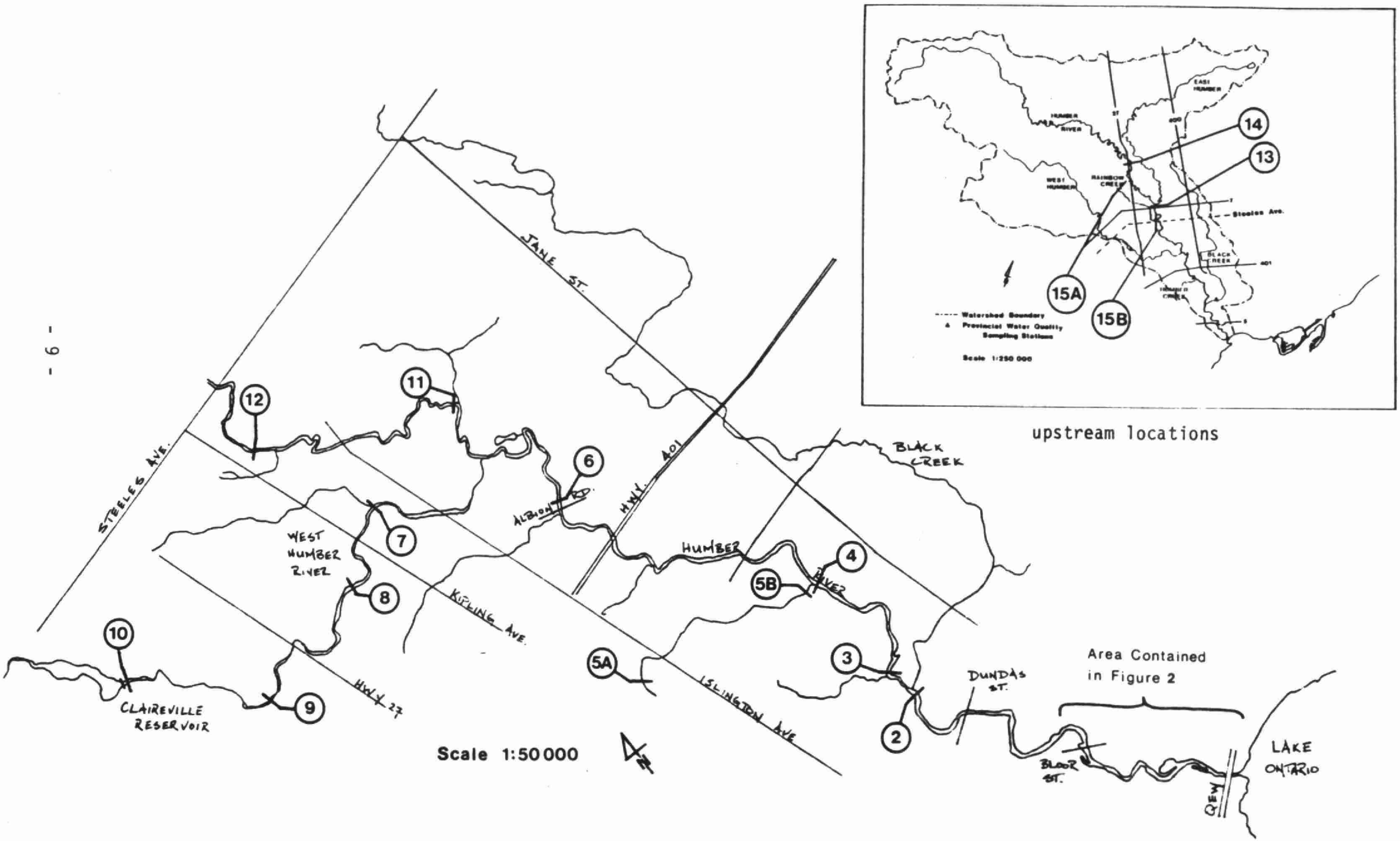

Figure 3 Cross-section Locations - Steeles Avenue to Bloor Street

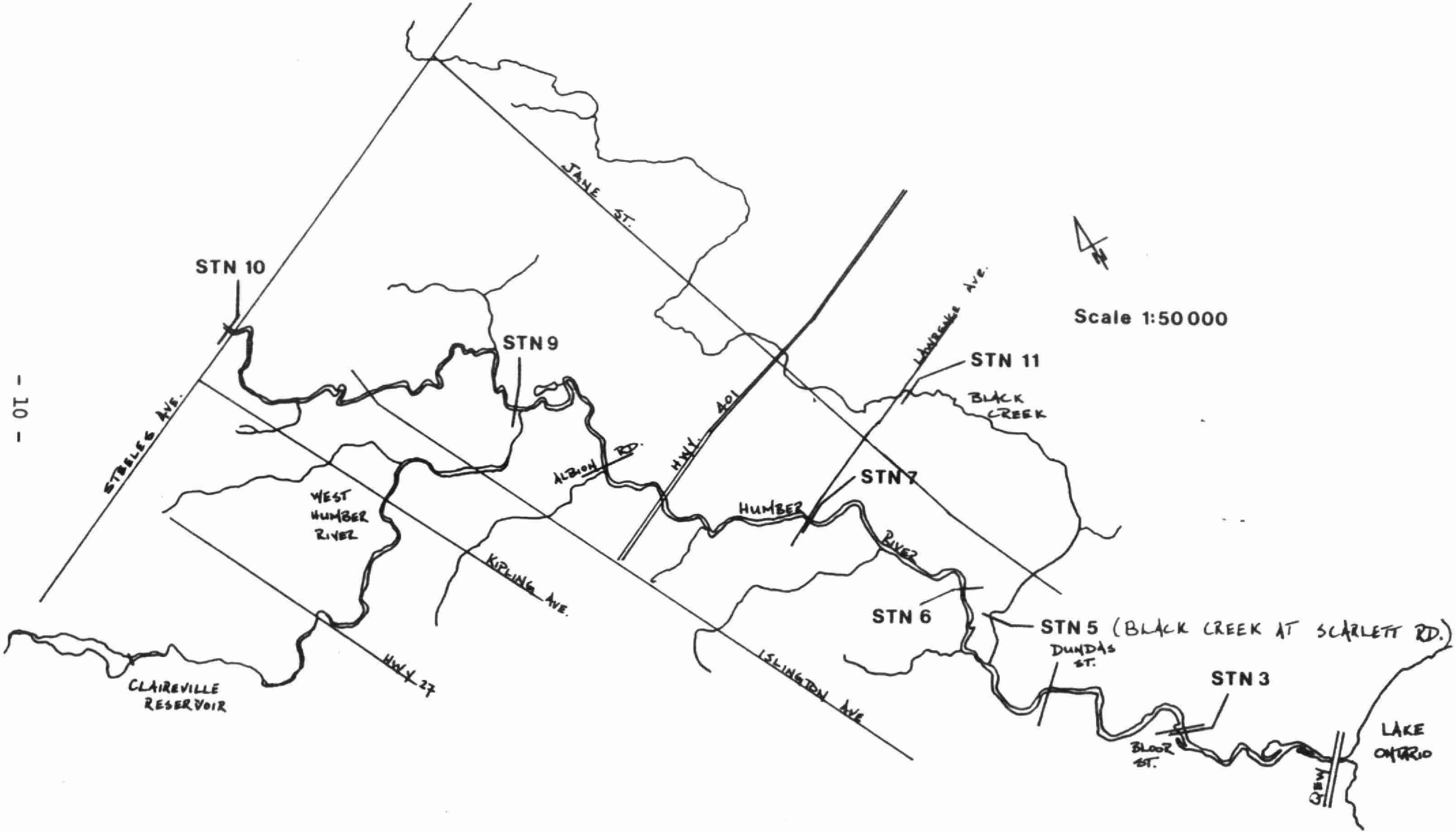

Figure 4 Locations of River Sampling Stations

4. Results

4.1 River Profile and Channel Geometry

Results from this survey include a profile of the Humber River, cross-sectional plots, widths, average depths, areas, and cumulative distances from Steeles Avenue to the mouth of the Humber River. Figure 5 shows the profile of the Humber River and major tributaries, and the cross-section locations. Cross-sections taken along the reach from the mouth of the Humber River to Bloor Street are identified by a cross-section number only. The remainder of the cross-sections taken from Bloor Street upstream are designated by X, followed by the cross-section number. River sampling stations are marked STN. A complete set of all 20 cross-sectional plots taken along the reach from the mouth of the Humber River to Bloor Street is presented in Figures A1 - A20, Appendix A. Plots of the cross-sections taken above Bloor Street to Steeles Avenue are shown in Figures B1 - B6, Appendix B. Plots of the cross-sections taken along the Humber River above Steeles Avenue and along the tributaries shown in Figure 5 are shown in Figures C1 - C10, Appendix C.

From Figure 5, it can be seen that the portion of the Humber River below Steeles Avenue can be sub-divided into three distinct reaches based on the bed slope. The first reach, starting at the mouth of the river (cross-section #1), extends up to Bloor Street (STN 3). This portion of the river is extremely flat and has an average slope of 0.05%. The second reach extends from Bloor Street to Highway 401, and has an increased slope, averaging 0.40%. The third reach extends from Highway 401 to Steeles Avenue. This portion of the Humber River has an average slope of 0.06%, similar to that of reach 1.

A summary of the cross-section data is presented in Table 2. From this summary it can be seen that for reach 1 stream width varies from 36 m - 85 m, while the average depth ranges from 0.52 m - 2.11 m. The weighted average width and depth along the reach are 55.0 m and 1.48 m respectively.

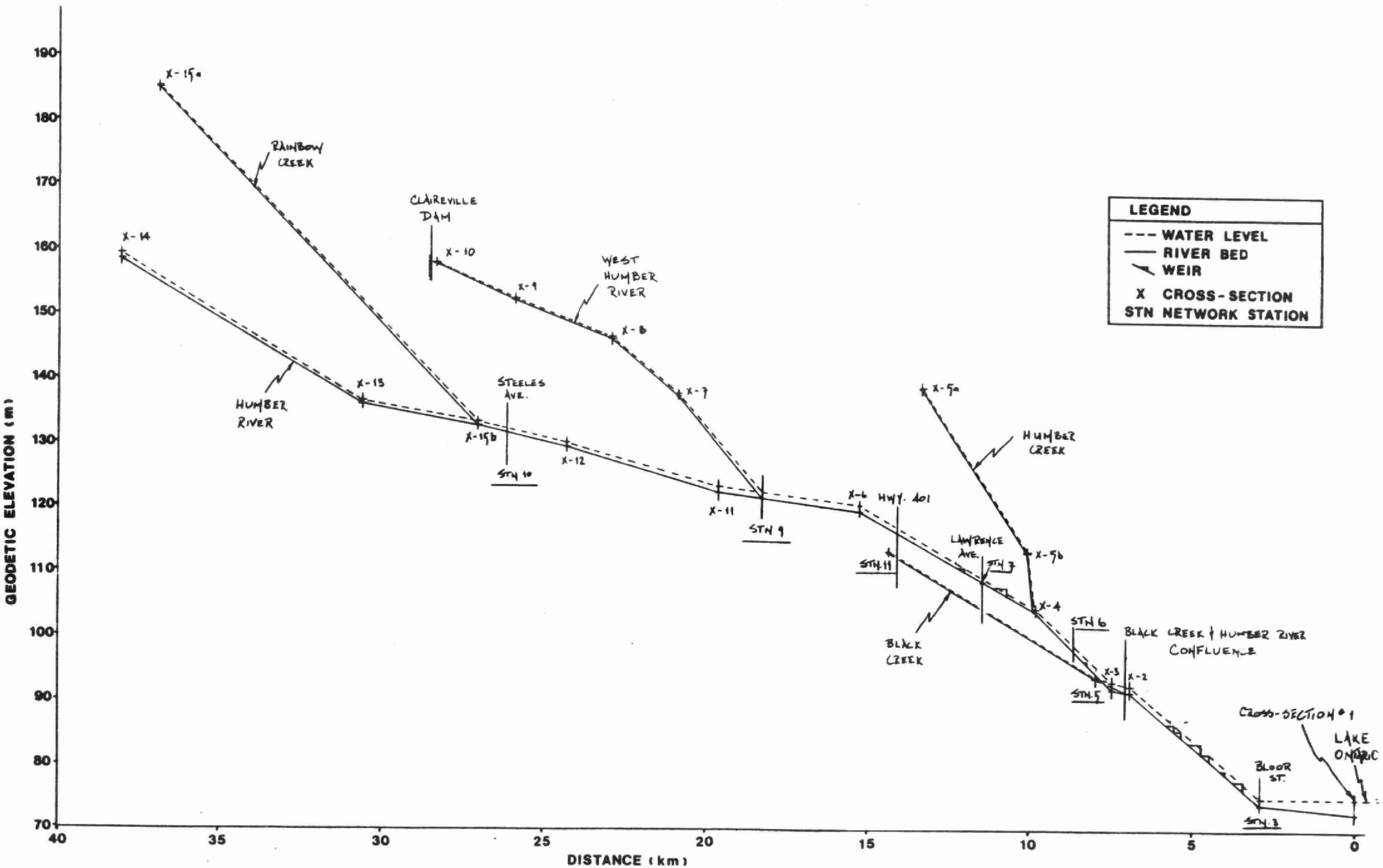

Figure 5 Profile of the Humber River and Tributaries

Table 2 : Cross-section Data Summary

Cross-section	Cumulative Distance From Lake (m)	Width(m)	Avg.Depth(m)	Area(m^2)
Humber River				
Reach 1 (Total Length 2930 m)				
1	0	85	1.84	156.7
2	230	75	1.96	146.7
3	310	60	2.11	126.5
4	420	78	1.51	118.0
5*	575	51	1.73	88.2
6	675	46	1.77	81.3
7	815	40	2.07	82.6
8	885	60	1.48	88.9
9	965	68	1.31	89.2
10*	1075	63	1.32	83.0
11	1330	36	1.99	71.7
12	1500	64	1.15	73.8
13	1740	38	2.04	77.5
14	1920	60	0.99	61.1
15	2120	35	1.96	68.6
16	2260	55	1.02	56.1
17	2400	50	0.95	48.5
18	2640	49	0.92	45.1
19	2730	56	0.54	28.9
20	2930	50	0.52	24.8
Reach 2 (Total Length 11230 m)				
STN3**	2930			
X-2	6935	35	0.14	4.7
Confluence with Black Creek**	7075			
X-3	7595	36	0.35	12.9
STN6**	8265			
X-4	9895	25	0.14	3.4
STN7**	11530			
HWY 401**	14160			

* Calculations made using main channel only - excluding side pond
** No cross-section taken

Table 2 : Cross-section Data Summary (cont'd)

Cross-section	Cumulative Distance From Lake (m)	Width(m)	Avg.Depth(m)	Area(m^2)
Reach 3 (Total Length 12010 m)				
X-6	15290	26	0.48	12.5
Confluence with West Humber** (STN9)	18320			
X-11	19610	14	0.45	6.5
X-12	24270	25	0.26	6.5
STN10**	26170			
Upper Humber River (North of Steeles Avenue)				
X-13	30600	26	0.33	8.7
X-14	38030	12	0.52	6.2
West Humber River				
X-7	20870	9	0.22	1.9
X-8	22950	11	0.05	0.50
X-9	25830	28	0.06	1.3
X-10	28310	17	0.03	0.54
Claireville Dam**	28500			
Rainbow Creek				
X-15A	36840	1.7	0.06	0.10
X-15B	27030	4.3	0.34	1.5
Humber Creek				
X-5A	13400	5.3	0.10	0.54
X-5B	10150	7.2	0.05	0.35
Black Creek				
STN5**	8015			
STN11**	14385			

** No cross-section taken

Cross-sectional area ranges from 24.8 m^2 at Bloor Street to 156.7 m^2 at the mouth of the Humber River. The width and average depth along reaches 2 and 3 are fairly consistent, with widths ranging from 14 m - 36 m and average depths from 0.14 m - 0.48 m. Areas were also consistent, ranging from 3.4 m^2 - 12.9 m^2. Weighted average widths and depths were not calculated for reaches 2 and 3 because of the relatively low number of cross-sections taken along these reaches.

4.2 Sediment Deposition Mapping

The velocity of a river can be utilized as an indicator of zones where sediment deposition is likely to occur. Reaches with reduced velocities are likely to be areas of sediment deposition; thus, the areas identified in the previous section as having reduced velocities (in particular the area from Bloor Street to the mouth) were surveyed intensively for sediment accumulation. Results from this survey show the locations, areal extent, depths and composition of the deposits, as well as an estimate of the volumes of the various types of sediment. In general, the term "sediment deposits" refers to material which has been transported from an upstream area and then deposited when the velocity and turbulence in the stream are reduced; this describes the majority of material present along a river bed. For this report however, a differentiation between bed material and deposited sediment will be based on the likelihood of movement of the material within a given time span. "Sediment" will be used to refer to that portion of material that is constantly undergoing change (transport - deposition - resuspension) while "bed material" is used to refer to material that appears to be more permanently consolidated in the river bed.

4.2.1 Sediment Deposition in Reach 1

The results of the sediment survey along reach 1 are summarized in Figures 6 and 7. Plots of the cross-sections show the limit of the

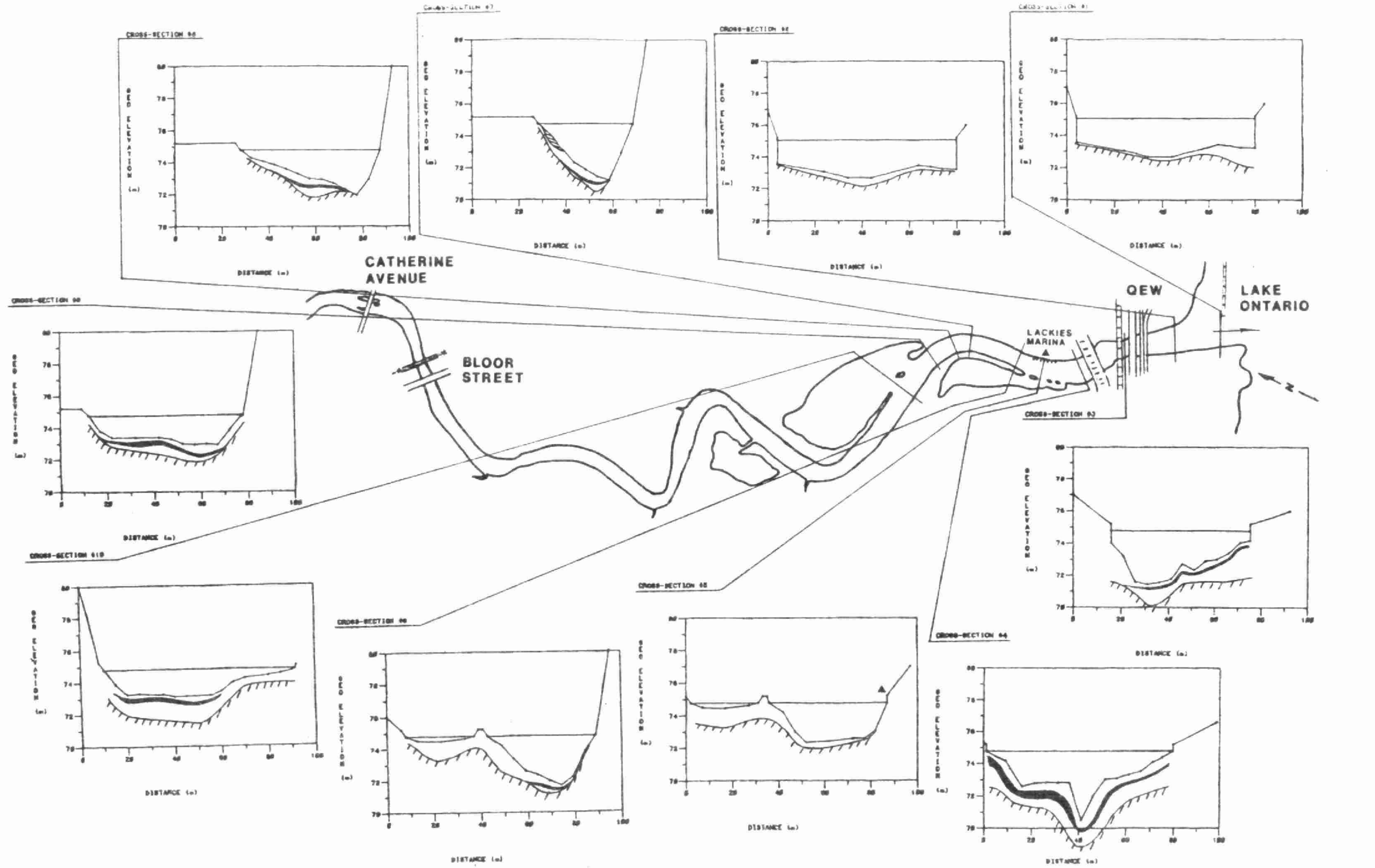

Figure 6 Sediment Mapping Results - Reach 1 - Stations 1 to 10

SEDIMENT TYPES: ORGANIC CLAY/SILT SAND
LIMIT OF MOVEABLE BED:

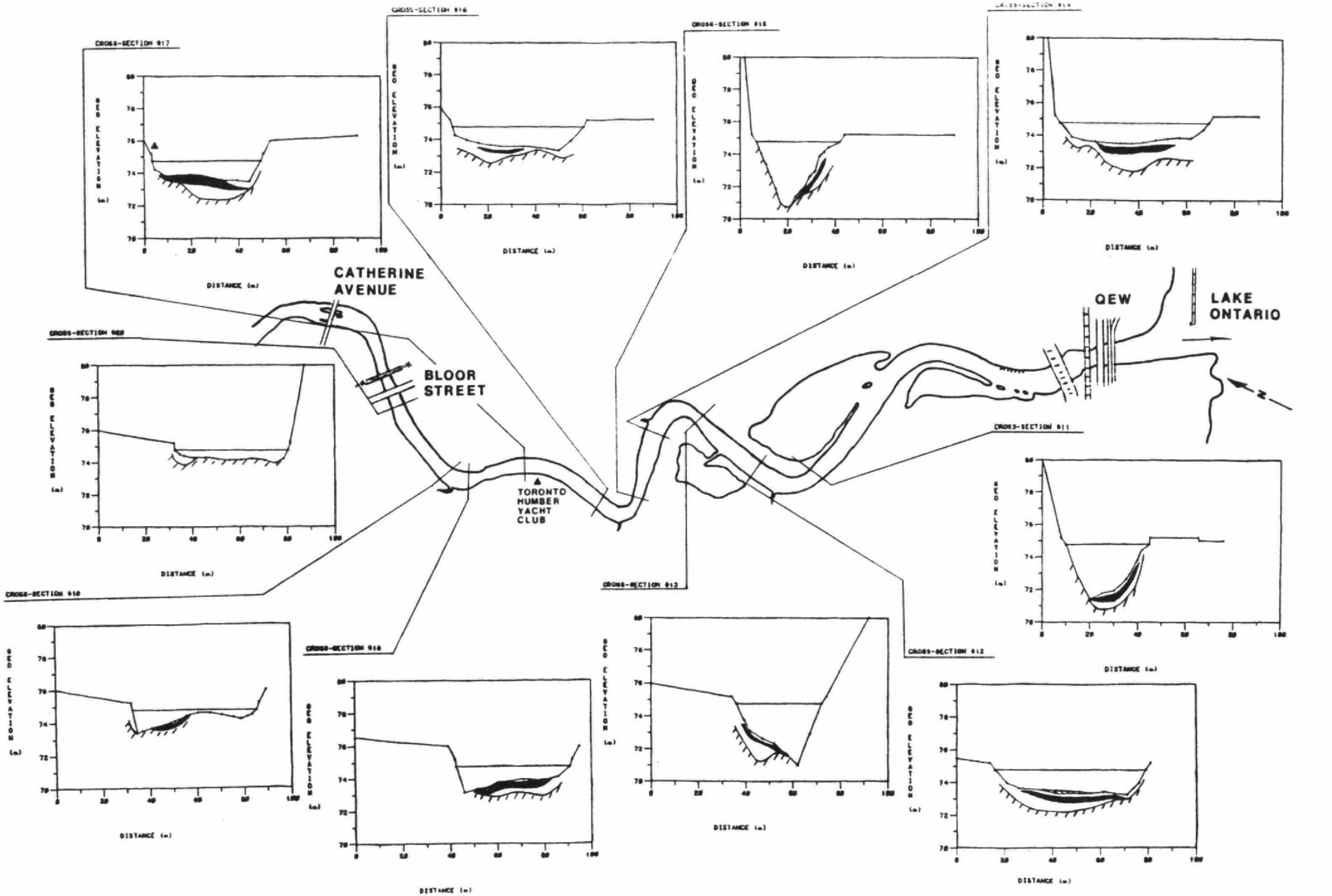

Figure 7 Sediment Mapping Results - Reach 1 - Stations 11 to 20

SEDIMENT TYPES: ORGANIC CLAY/SILT SAND
LIMIT OF MOVEABLE BED:

moveable bed as well as any layering of sediment types. The composition shown was not obtained from grain size analyses, but is an approximation from the soundings: the nature of each layer was inferred from the ease with which the sounding rod had penetrated it. Organic and loosely consolidated clay/silt material can be penetrated easily by a sounding rod, whereas sand and highly consolidated clay/silt material are much more difficult to penetrate.

Generally, the deposited sediment was found to be stratified along the section in the following manner: a bottom layer of clay/silt material, a mid-layer of silty-sand material and an overlying layer of clay/silt sediment. The total depth of penetrable sediment ranged from 1.5 m - 2.0 m at the Queen Elizabeth Way bridge to 0.10 m - 0.20 m at cross-section #20 near Bloor Street.

There are two marinas located within reach 1, both receiving considerable boat traffic. One is situated on the east bank of the Humber River at cross-section # 5, and as shown in Figure 6 the amount of sediment deposition near the marina is minimal. The other marina is situated on the west bank of the Humber River downstream of cross-section # 17. Some sediment deposition has occurred on the same side as this marina but to a lesser extent than in the rest of the channel (see Figure 7).

4.2.2 Sediment Deposition in Reaches 2 and 3

Figure 8 illustrates the areas where sediment deposits were located along reaches 2 and 3. Figures 9 to 15 are maps of specific locations of sediment deposition described within this section. The remainder of the maps of sediment deposition zones are located in Appendix D.

Reach 2 contains ten weirs, which are shown in Figure 8 (stations 21 to 29). Only four of the ten weirs within reach 2 contained any significant sediment deposits as shown in Figures 9 to 12. The sediment deposits generally were located across the entire channel, however, the area immediately upstream of each weir (approximately

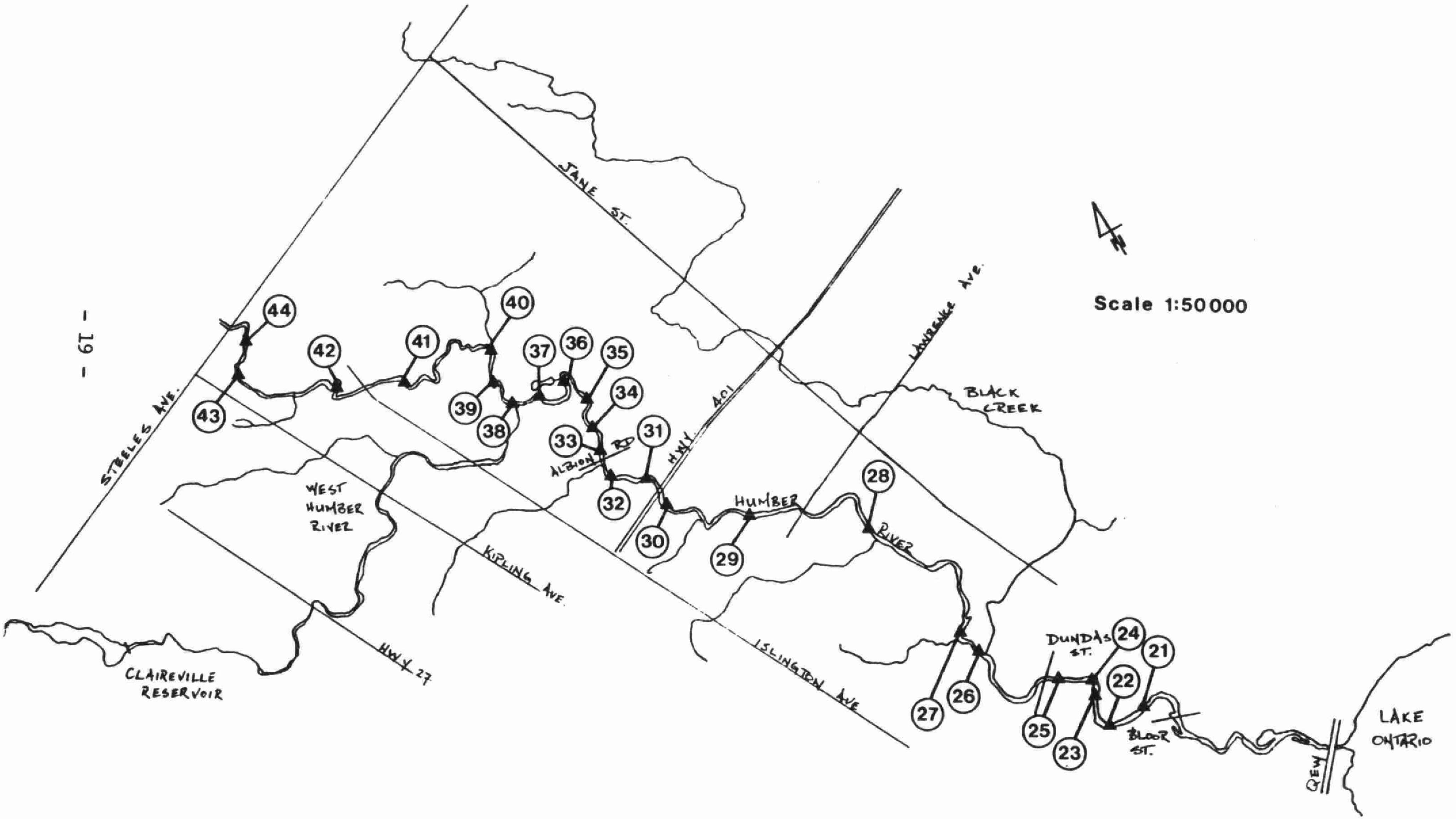

Figure 8 Location of Sediment Deposition Zones Within Reaches 2 and 3

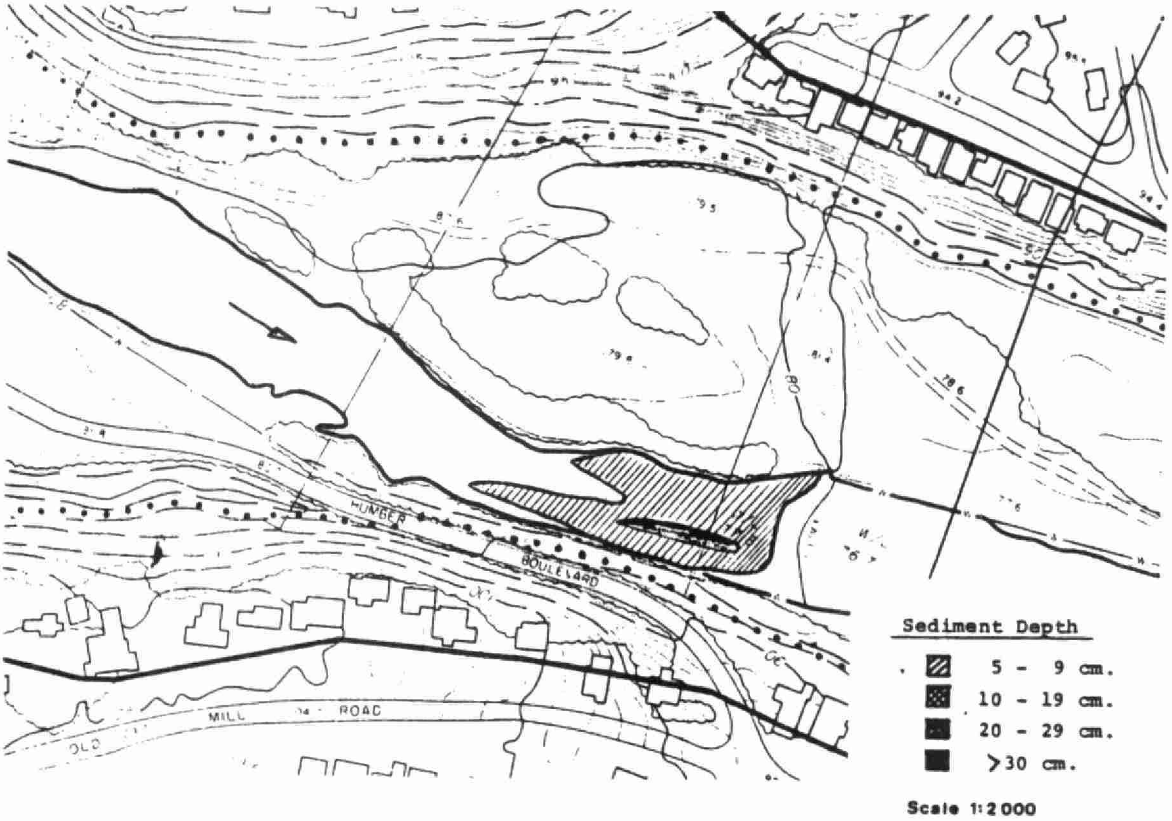

Figure 9 Topographic Map of Sediment Deposition - Zone # 21

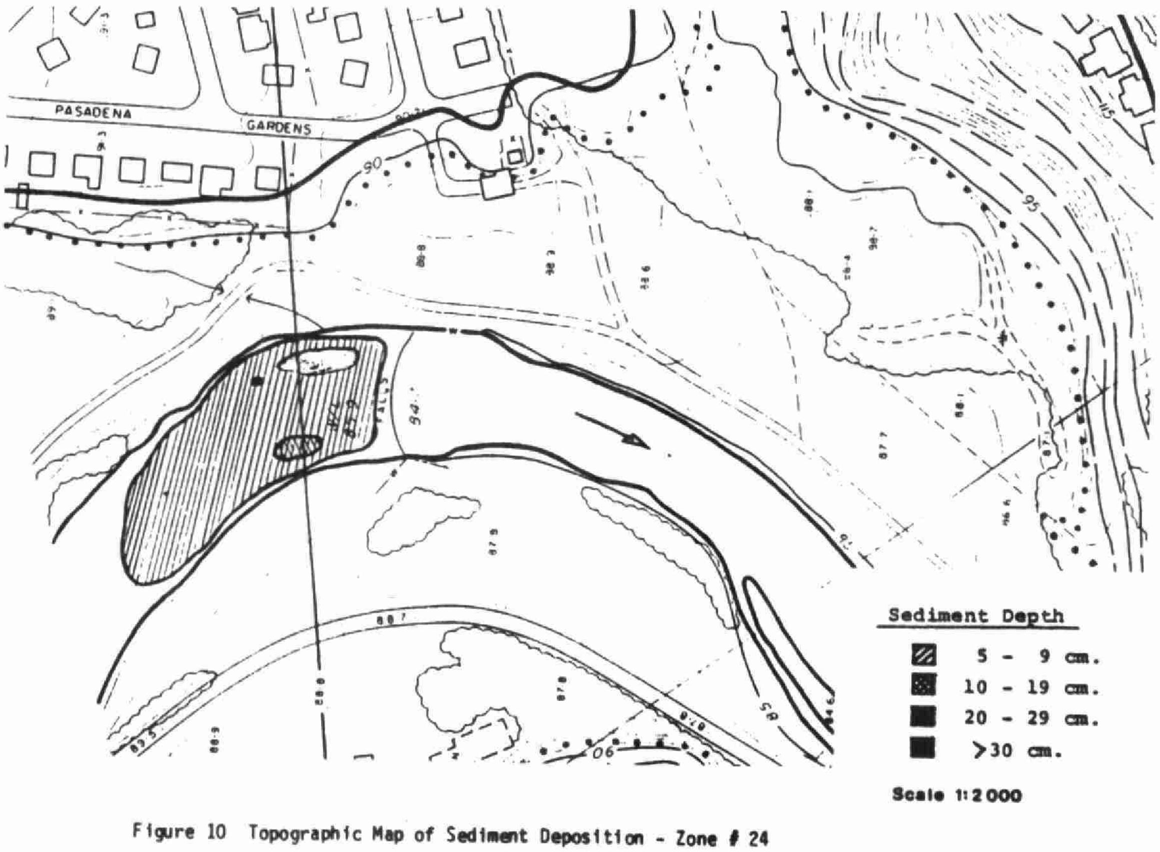

Figure 10 Topographic Map of Sediment Deposition - Zone # 24

Figure 11 Topographic Map of Sediment Deposition - Zone # 25

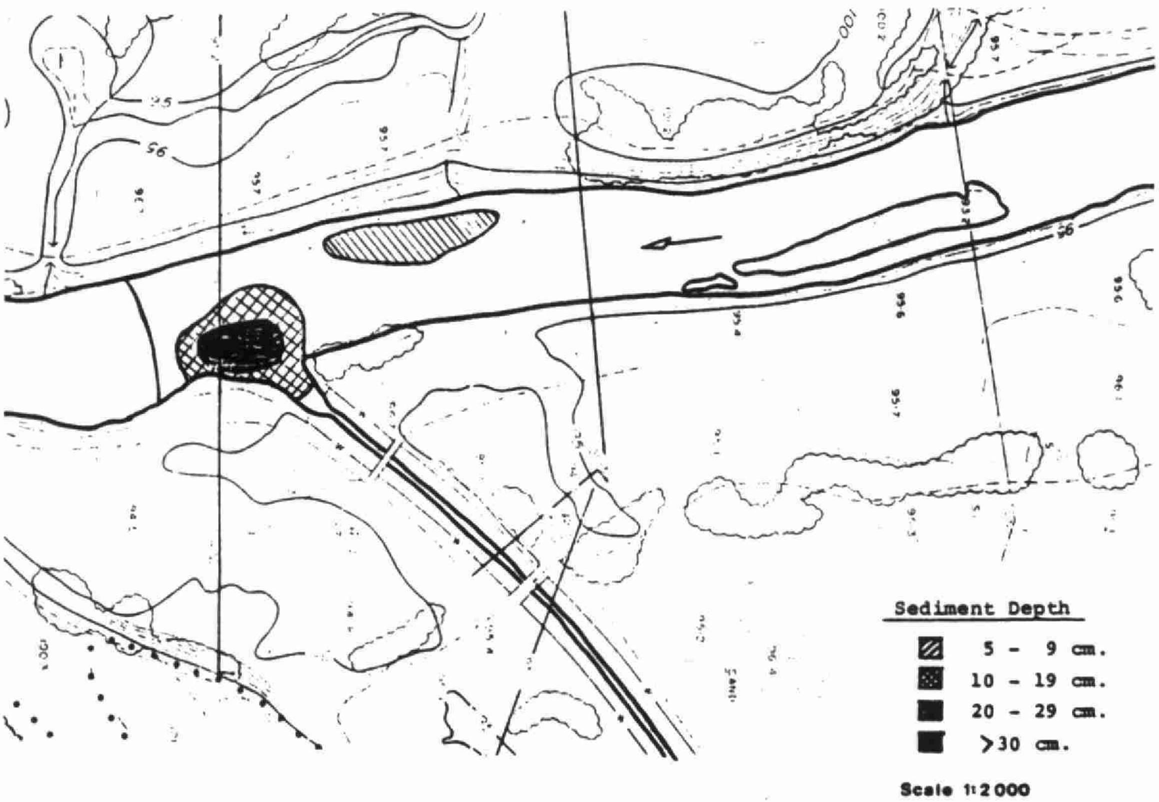

Figure 12 Topographic Map of Sediment Deposition - Zone # 26

10 m upstream of the structure) was free of sediment. The increased turbulence behind the weir is likely responsible for this phenomenon.

The sediments behind the weirs consisted mainly of clay/silt sized particles and large amounts of organic material. There was a very small amount of sandy material present. A layering of sediment, as found along reach 1, was present behind only one of the weirs. The weir below the confluence of Black Creek and the Humber River (station 26) was the most heavily silted of all the weirs. As shown in Figure 11, the area is located directly in line with Black Creek and is made up of layers of 0.20 m organic material on the surface, 0.20 m of silty sand material and a deep layer 0.80 m thick of clay/silt particles.

Bed material between the weirs along reach 2 consisted mainly of cobbles and boulders*; the river bed in this reach can therefore be considered to be armoured.

The slope of reach 3 begins to decrease at Highway 401, and approaches 0.06% (similar to reach 1) just upstream of Albion Road. Sediment deposits were minimal within this area (see Figure 13).

There is a considerable decrease in the velocity of the Humber River upstream of Albion Road coupled with significant sediment deposition, as shown in Figure 14. This zone of deposition stretches upstream from Albion Road for approximately 400 m. The majority of the sediment deposits along this section were a mixture of silt and sand material.

Beyond this section of reduced velocity above Albion Road and continuing upstream to the confluence with the West Humber River,

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*Bed material size designations based on the Unified Soil Classification System (see for example Wagner, 1957) are as follows: gravel (0.06 m maximum diameter), cobbles (0.20 m maximum diameter), and boulders (0.60 m maximum diameter).

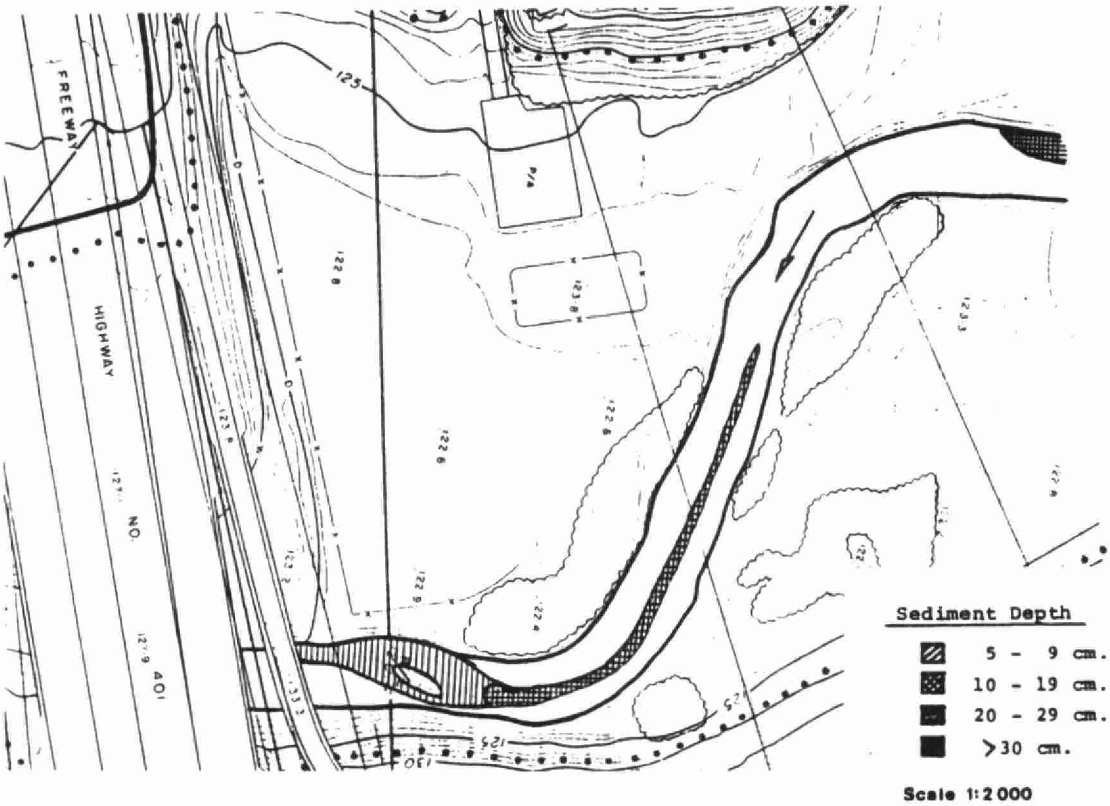

Figure 13 Topographic Map of Sediment Deposition - Zone # 31

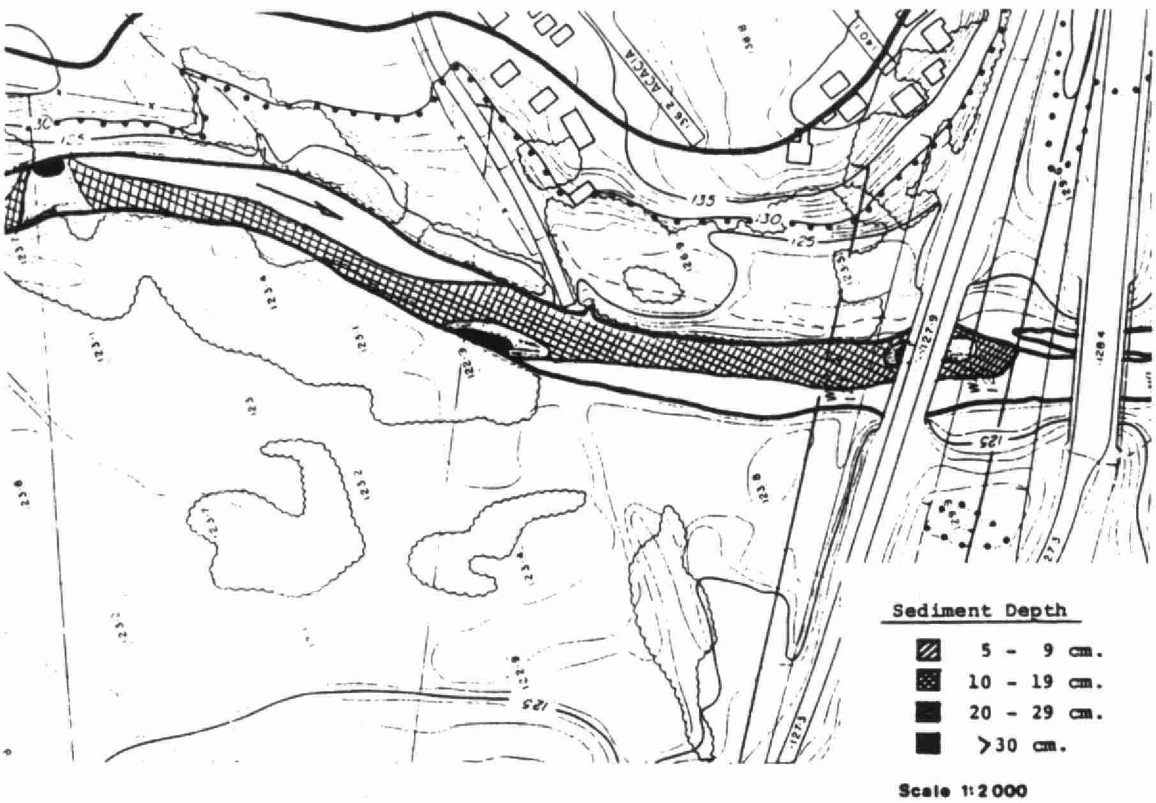

Figure 14 Topographic Map of Sediment Deposition - Zone # 33

the slope of the Humber River begins to increase. There were only a few small pockets of clay/silt deposits within this section, as shown in Figure 15. Bed material consisted mainly of gravel.

Upstream of the confluence of the Main and West Humber Rivers, the slope of the Humber River increases significantly. Bed material there was made up of gravel and cobbles.

Occcasional patches of sediment accumulation occurred in reach 3. These consisted mainly of a mixture of silt and sand material with small areas of organic and clay materials.

The volume of the sediment deposits can be estimated from the depth and areal distribution measurements. Table 3 presents a summary of these volume estimates for each of the three reaches.

4.3 Time of Travel

A relationship between time of travel and flow was established for the reaches between the river sampling stations shown in Figure 4. These river sampling stations were established during a previous survey conducted in the fall of 1982. The reaches cover the length of the Humber River from Steeles Avenue to Bloor Street and Black Creek from Lawrence Avenue to Scarlett Road. No time of travel-versus-flow relationship was established for the reach below Bloor Street due to the relatively low velocity along this reach and the consequent difficulty of measuring a diffuse dye plug (see Table 1 (3)).

Plots of the time of travel-versus-flow relationships are shown in Figures 16 and 17. A summary of the flow rate and time of travel data is presented in Table 4. Table 5 shows the hydraulic relationships and coefficients for each reach along the Humber River based on the time of travel data. Cross-section and flow data for Black Creek were relatively limited; therefore no relationships were calculated. The amount of data available for the reaches along the

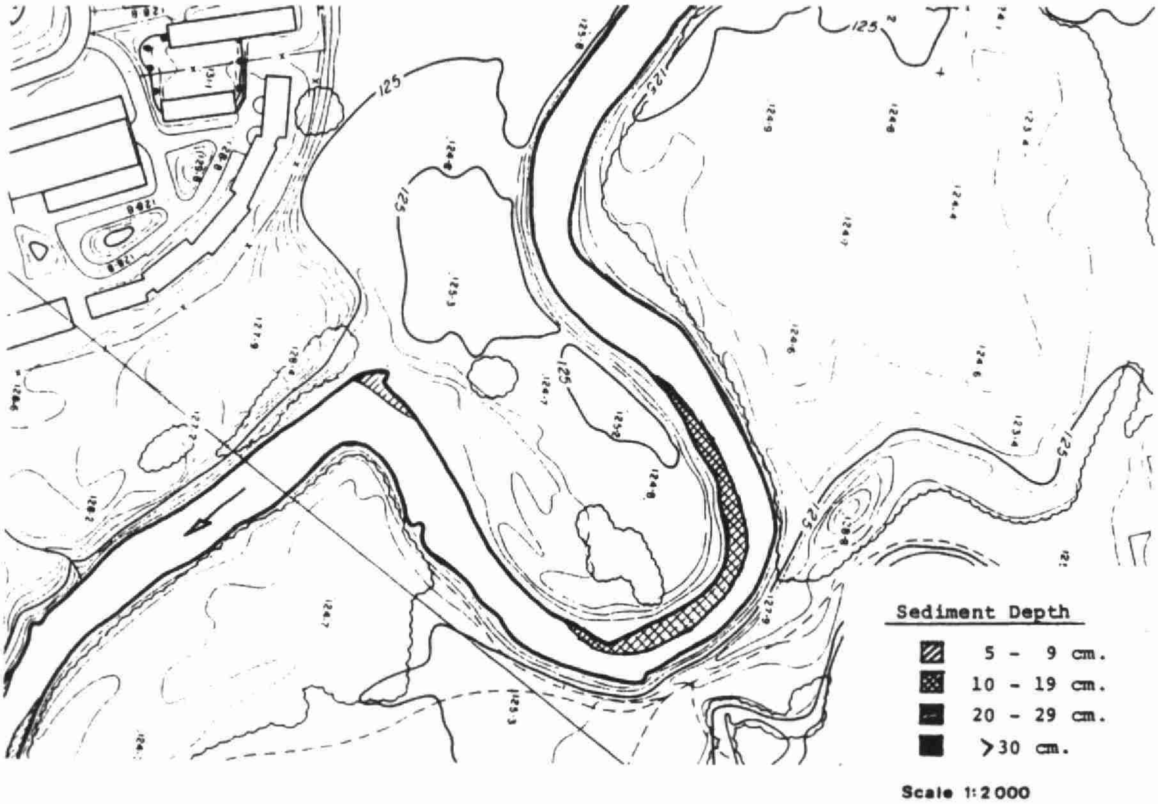

Figure 15 Topographic Map of Sediment Deposition - Zone # 37

Table 3: Summary of Volume Estimates of Sediment Deposits

Reach	Sediment Type			Total Volume per Reach	Total Volume per Reach / Total volume (all Reaches)
	Organic (m^3)	Clay/Silt (m^3)	Silty-Sand (m^3)	(m^3)	(percent)
1	2,400*	64,100*	13,500*	80,000*	96.0
2	800	440	75	1,315	1.6
3	260	700	1,100	2,060	2.4
				83,375	100.0

* The estimates for reach 1 include only those sediments located along the main channel and exclude sediment present in the large side ponds at stations 6, 10 & 12 (see Figures 5 and 6).

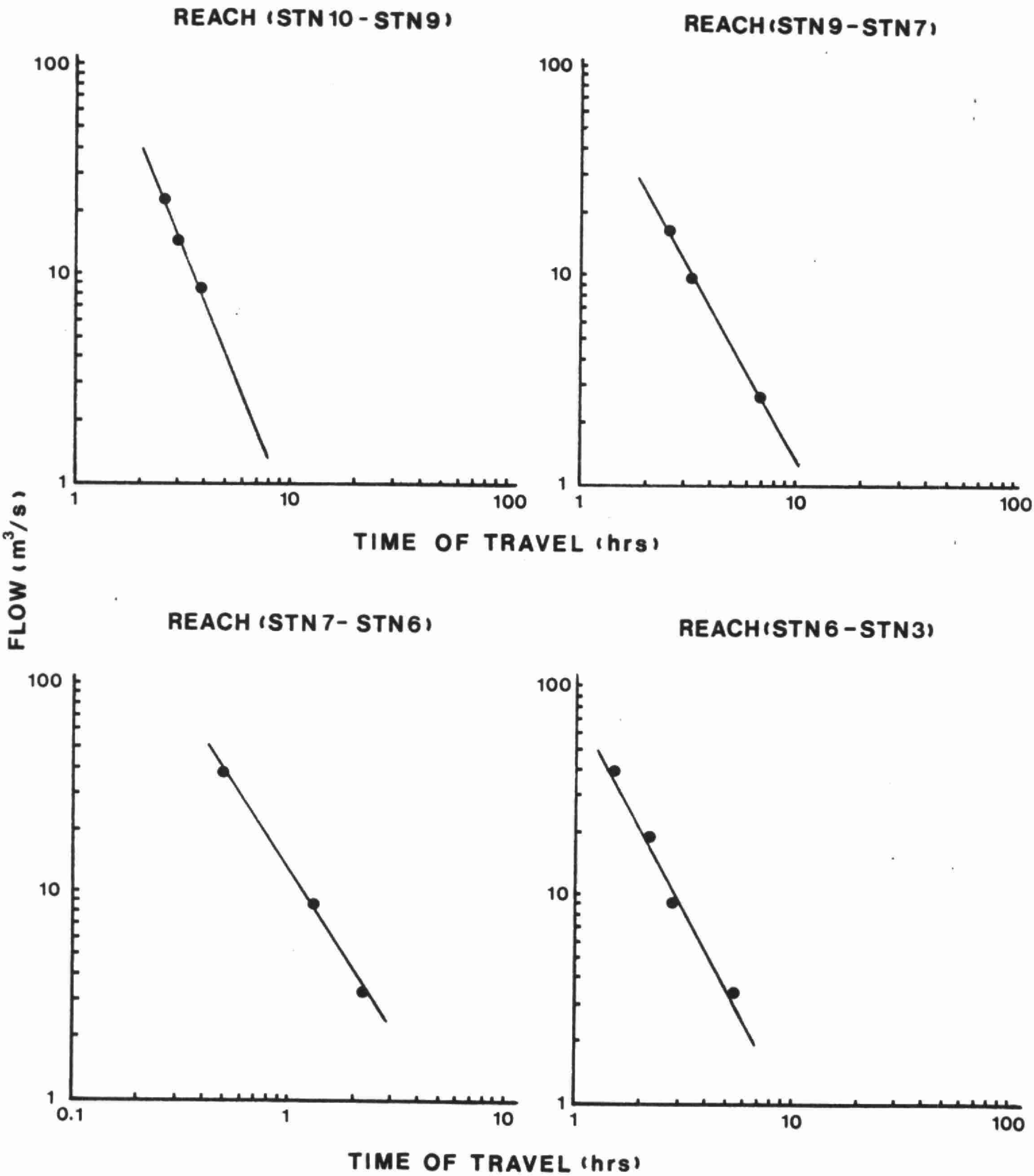

Figure 16 Time of Travel - Flow Relationships for the Humber River

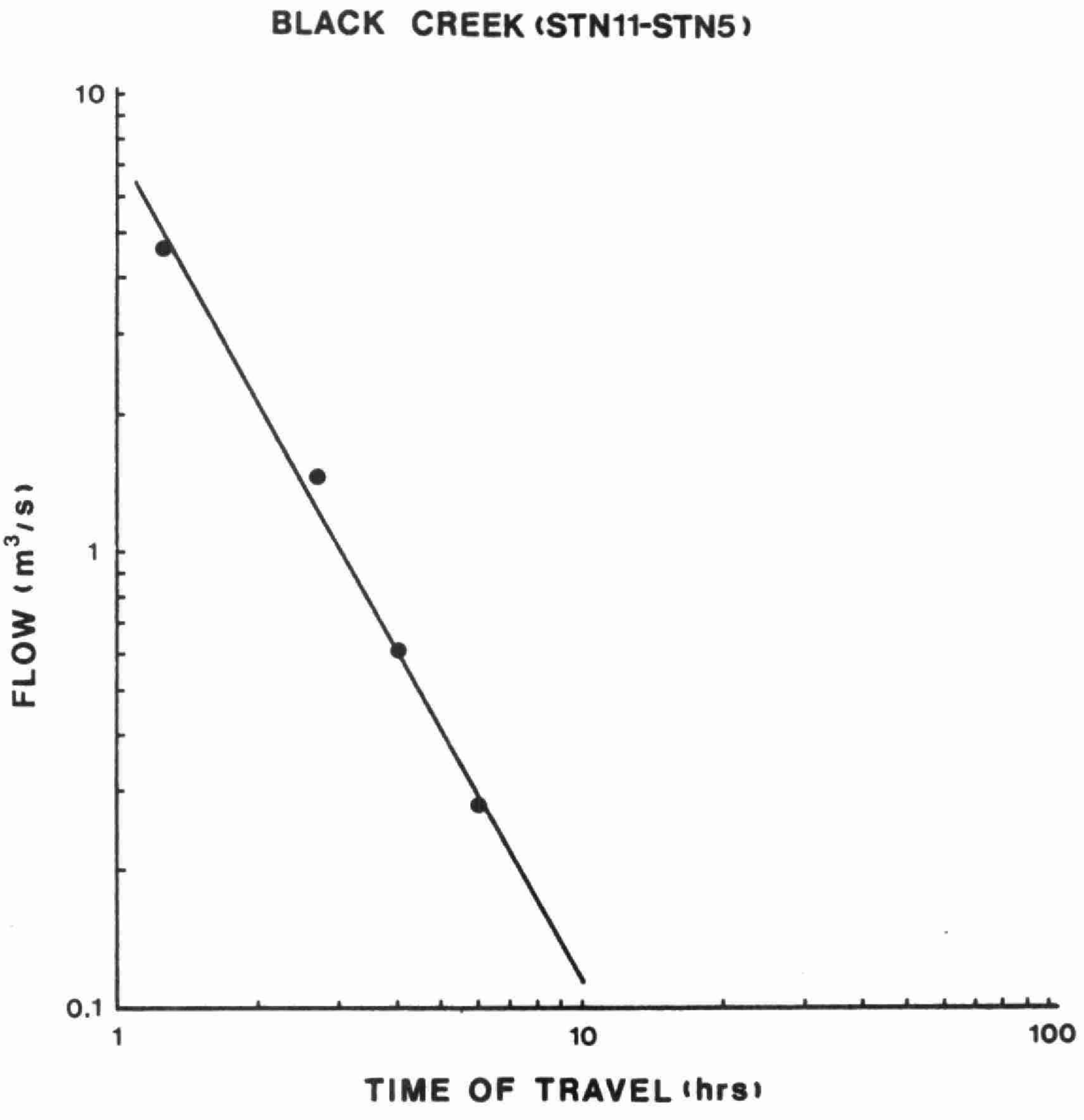

Figure 17 Time of Travel - Flow Relationship for Black Creek

Table 4 : Summary of Flow and Time of Travel Data

Date	Oct. 14/82		Nov. 3/82		Nov. 4/82		Dec. 1/82		Dec. 2/82	
Reach	FLOW (cms)*	TOT (hrs)	FLOW (cms)*	TOT (hrs)	FLOW (cms)*	TOT (hrs)	FLOW (cms)*	TOT (hrs)	FLOW (cms)*	TOT (hrs)
STN 10 - STN 9	-	-	14.26	2.97	22.53	2.60	8.47	3.83	-	-
STN 9 - STN 7	2.67	6.83	16.20	2.60	-	-	9.70	3.25	-	-
STN 7 - STN 6**	3.33	2.23	-	-	37.49	0.50	-	-	8.75	1.30
STN 6 - STN 3	3.44	5.42	19.01	2.17	39.59	1.50	-	-	9.21	2.78
STN 11 - STN 5	0.28	6.00	1.47	2.67	4.66	1.25	0.61	4.03	-	-

*Cubic metres per second

**No flows available for STN 7 on the days these measurements were taken. Relationship developed based on flow at STN 6 only.

Table 5 : Hydraulic Relationships & Coefficients*

Depth (m): $H = aQ^d$
Velocity (m/sec): $V = bQ^f$
Width (m): $W = cQ^g$
TOT (hrs): $T = b_tQ^{-f}$

where Q = Flow (m^3/s)

Reach	a	b	b_t	c	d	f	g
10 - 9	0.309	0.247	8.833	13.120	0.472	0.397	0.131
9 - 7	0.455	0.161	11.708	13.640	0.238	0.555	0.207
7 - 6	0.272	0.187	4.845	19.626	0.217	0.623	0.160
6 - 3	0.328	0.154	9.612	19.787	0.288	0.512	0.200
11 - 5	-	-	3.064	-	-	0.553	-

*The coefficients a, b, b_t, c, d, f and g were developed by Leopold and Maddock for streamflow with d, f and g being dimensionless. For further information see, "Stream Water Quality Assessment Procedures Manual", Water Resources Branch, Ontario Ministry of the Environment, March 1980.

Humber River was also limited, and as such, the values listed in Table 5 represent the best estimates for the various coefficients at the present time.

5. Discussion

5.1 River Profile and Channel Geometry

A U-shaped channel was found to be typical of the section of the Humber River from Steeles Avenue to the mouth. However, the slope of reach 1 as well as the action of Lake Ontario greatly reduces the velocity of the Humber River below Bloor Street. The corresponding high cross-sectional area is also indicative of a reduced velocity (see Table 2). The range of flow-through areas also indicates that the velocity at Lake Ontario will be lower than that at Bloor Street by approximately a factor of five (area at Lake Ontario is five times as great as the area at Bloor Street). Despite the relatively low velocity of reach 1, the reach does contain a few localized areas of bank erosion. This erosion has likely occurred during periods of high flow.

Table 2 illustrates the lower cross-sectional area which exists along reach 2 (3.4 - 12.9 m^2) as compared to that of reach 1 (24.8 - 156.7 m^2). These lower areas indicate that the velocity will remain relatively high throughout the reach. There are ten weirs located throughout reach 2, which were constructed for erosion control. The impoundments produced as a result of these weirs are relatively small due to the low heights of the weirs (0.2 - 1.4 m); however, the weirs are effective in trapping sediment as will be discussed in the next section. The amount of bank erosion along reach 2 is minimal as a result of the weirs and permanent bank structures constructed along the reach.

The slope of reach 3 is similar to that of reach 1. The reduction in velocity along reach 3 is not as great as the reduction in reach 1. The presence of Lake Ontario influences reach 1 such that the velocity approaches zero, while at Albion Road a significant velocity is maintained. Stream banks along reach 3 appear to be stable; however, where the soils were exposed, the banks were subject to varying degrees of erosion.

5.2 Sediment Deposition

5.2.1 Patterns of Sediment Accumulation

Where, how, and in what volume sediment is deposited in a river reach depends on the hydraulic characteristics of the reach, on sediment availability and on the nature of the sediment particles. The depth and velocity of flow in a given reach changes with season and meteorological conditions, producing variations in the pattern of sedimentation within the reach.

In reach 1 of the Humber River the velocity of flow was very low, allowing substantial sediment deposition to take place. Areas of minimal sediment deposition in reach 1 tended to be located at bends in the river, away from the centre of curvature, where higher velocities are maintained (see for example Figures 6 & 7, cross-sections 7, 11, 13, 15 and 18). Reach 2 has a relatively steep slope with corresponding high velocity and reduced sediment deposition. In reach 3, the amount of deposited sediment was less than in reach 1. Although reach 3 has a slope similar to reach 1, it lacks the influence of the lake, which was significant in reducing flow velocities in reach 1. Only a relatively small amount of fine material was deposited along reach 3, suggesting that moderately high velocities are maintained in the reach.

A variety of man-made structures alter the patterns of sediment deposition in the river. The localized influence of boat traffic along reach 1 is illustrated in Figures 6 and 7. The amount of sediment deposition near the two marinas is less than that shown at adjacent sampling stations, although the impact of the marina near cross-section # 17 is somewhat less than that of the marina at cross-section # 5.

A number of weirs present along reach 2 allow some localized sediment deposition there. The sediment within reach 2 contained

very little sand; this may be due to the low head loss across the weirs. When the flow is high enough to move sand size particles, possibly moved from the area above Albion Road, then the particles can overflow the weirs and will likely be deposited in reach 1 or in Lake Ontario. During declining flows after the spring runoff, the sand particles will be trapped above Albion Road and will not have an opportunity to be deposited behind the weirs. The impoundment behind the weir at Black Creek does, however, contain sand sized particles. This may be a result of the height of the weir and the reduced slope at the Black Creek-Humber River confluence (see Figure 5).

5.2.2 Sediment Volume and Mass

The amount of sediment generated within the Humber River watershed can be estimated using the nomographs of Linsley, Kohler and Paulhus (1982) which relate either mean annual precipitation occurring over the watershed or mean annual streamflow to mass of sediment produced annually. For the Humber River watershed, the mean annual precipitation method gives a value of 120×10^6 kg/yr sediment generated from the watershed, while the mean annual flow method gives a value of 242×10^6 kg/yr. Because few data exist to support either of these figures, this paper will consider them to represent the end points of a possible range of values.

Table 3 shows that approximately 80,000 m^3 of sediment has been deposited in reach 1. Calculations by Linsley and Franzini (1979) give a typical density of sediment as 850 kg/m^3. This yields a total mass of sediment within reach 1 of 80,000 m^3 x 850 kg/m^3 = 68×10^6 kg. Of this, the portion overlying the sand layer constitutes less than half (31,320 m^3 or 26.6×10^6 kg).

The presence of a sand lens in the sediment deposits (Figures 6 and 7) suggests that in a typical annual cycle only the upper layer of clay/silt material (and possibly a portion of the sand layer) are removed and flushed to Lake Ontario. This represents approximately

11 to 23% of the sediment produced from the Humber River watershed. It is likely that the entire depth of deposited sediment (which represents 28 to 57% of the watershed sediment) along reach 1 would only be removed during a major regional storm event. By contrast, little of the sediment transported to reaches 2 and 3 from the watershed appears to be retained in those reaches; it is instead moved down the river to reach 1 or the lake (see Table 3).

The implication of this sediment trapping pattern is that reach 1 acts as a temporary reservoir or stilling pond for a significant proportion of the sediment produced by the Humber River watershed. However, it should be noted that the preceding speculation on sediment movement is based on a single survey conducted late in the summer season. The deposited sediment present during July and August may not be representative of the total amount likely to accumulate over the depositional period. Walling (1977), however, has found that the majority of sediment movement occurs during a short period of time, specifically during the spring melt for the Great Lakes Region. Sampling outside of that period, then, should yield a realistic estimate of the amount of sedimentation occuring on an annual basis.

5.3 Time of Travel

The time of travel in a reach is directly related to the average velocity within the reach. Velocity will be influenced by slope, channel geometry and man-made structures.

In order to compare the time of travel versus flow relationships, a range of average reach velocities were calculated over a range of flows as outlined in Table 6. From Table 6 it can be seen that during periods of low flow, velocity is consistent throughout the reaches. At higher flows, the influence of slope becomes increasingly apparent. The reach from STN 7 to STN 6 has a steeper slope (see Figure 4) and a correspondingly higher velocity than the other reaches. The reach from STN 6 to STN 3 has a slope similar to

Table 6 : Time of Travel and Average Velocities

Reach (stations)	Reach Length(m)	Average Velocity Low Flow ($2\ m^3/s$)		Intermediate Flow ($10\ m^3/s$)		Peak Flow ($100\ m^3/s$)	
		TOT* (hrs)	VEL** (m/s)	TOT* (hrs)	VEL** (m/s)	TOT* (hrs)	VEL** (m/s)
Humber River							
10 - 9	7850	6.71	0.32	3.54	0.62	1.42	1.54
9 - 7	6790	7.96	0.24	3.26	0.58	0.91	2.07
7 - 6	3265	3.15	0.29	0.78	1.15	0.27	3.30
6 - 3	5335	6.74	0.22	2.96	0.50	0.91	1.63
	Total TOT*	24.56		10.54		3.51	
Black Creek	flow***	($0.2\ m^3/s$)		($2.0\ m^3/s$)		($10.0\ m^3/s$)	
11 - 5	6370	7.46	0.24	2.09	0.84	0.86	2.06

*TOT - Time of Travel

**VEL - Average velocity over the reach

***Flows on Black Creek selected to correspond to flows within the Humber River.

the reach from STN 7 to STN 6, but its velocity is lower probably because of the influence of the eight weirs constructed along this reach. Also shown in Table 6 is the total time of travel for the flow range, indicating that during peak flows, time of travel is lower by a factor of approximately 6 compared to that during low flow periods.

In general, the time of travel versus flow relationships for the Humber River and Black Creek are typical of Southern Ontario rivers (Bacchus, 1982, *), both in terms of average velocities and in the response to peak flows.

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* Data on file in the River Systems Assessment Unit, Water Resouces Branch - Grand River Basin.

6. Summary and Conclusions

1. A U-shaped channel was found to be typical of the section of the Humber River from Steeles Avenue to the mouth.

2. In the reach of the Humber River from Lake Ontario to Bloor Street (reach 1) the velocity of flow was very low, allowing substantial sediment deposition to take place. The reach from Bloor Street to Highway 401 (reach 2) has a relatively steep slope with corresponding high velocity and reduced sediment deposition. In the reach from Highway 401 to Steeles Avenue (reach 3), the amount of deposited sediment was less than that in reach 1 despite the reaches similar slopes. This is thought to be because reach 3 lacks the influence of Lake Ontario, which was significant in reducing flow velocities in reach 1.

3. Boat traffic tends to reduce sediment accumulation; however, the influence of boat traffic on the patterns of sediment deposition is limited to the areas adjacent to the two marinas.

4. Ninety-six percent of the deposited sediment along the Humber River is contained in reach 1. Between 77% and 89% of the sediment produced by the Humber River watershed annually is probably transported into Lake Ontario. Reach 1 acts as a temporary reservoir or stilling pond for a significant proportion of the sediment produced by the Humber River watershed.

5. The 4 weirs within reach 2 which contained sediment deposits, contained less than 1% of the estimated annual load. Of the sediments trapped by the weirs, 94% consisted of fine material (clay/silt and organic).

6. In general, the time of travel-versus-flow relationships for the Humber River and Black Creek are typical of Southern Ontario rivers. During periods of low flow, velocity is consistent throughout the Humber River and Black Creek, while at higher flow rates the reaches with steeper slopes have a correspondingly higher velocity. Total time of travel over the reaches along the Humber River is lower by a factor of approximately six during peak flows as compared to low flow periods.

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Bacchus, A.:"Physical Characteristics of the Avon River", Stratford/ Avon River Environmental Management Project, Technical Report S-2, 1982.

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APPENDIX A

Channel Cross-sectional Plots - Humber River
- Lake Ontario to Bloor Street

CROSS-SECTION #1

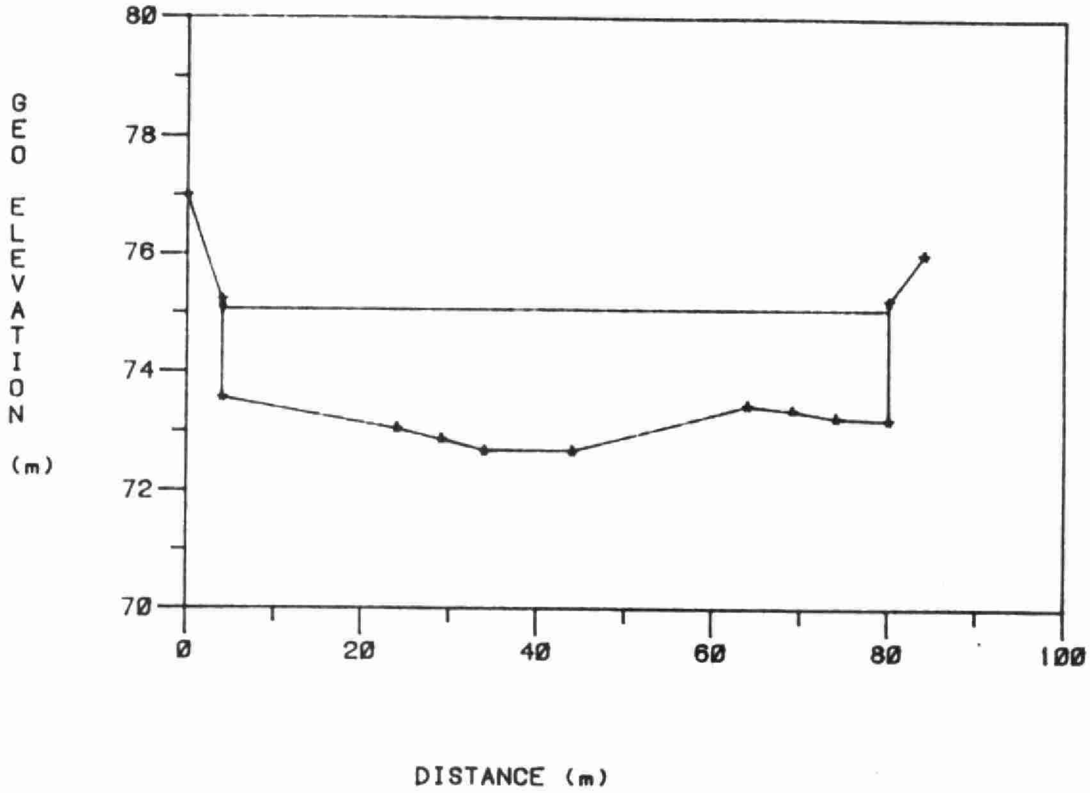

Figure A1

CROSS-SECTION #2

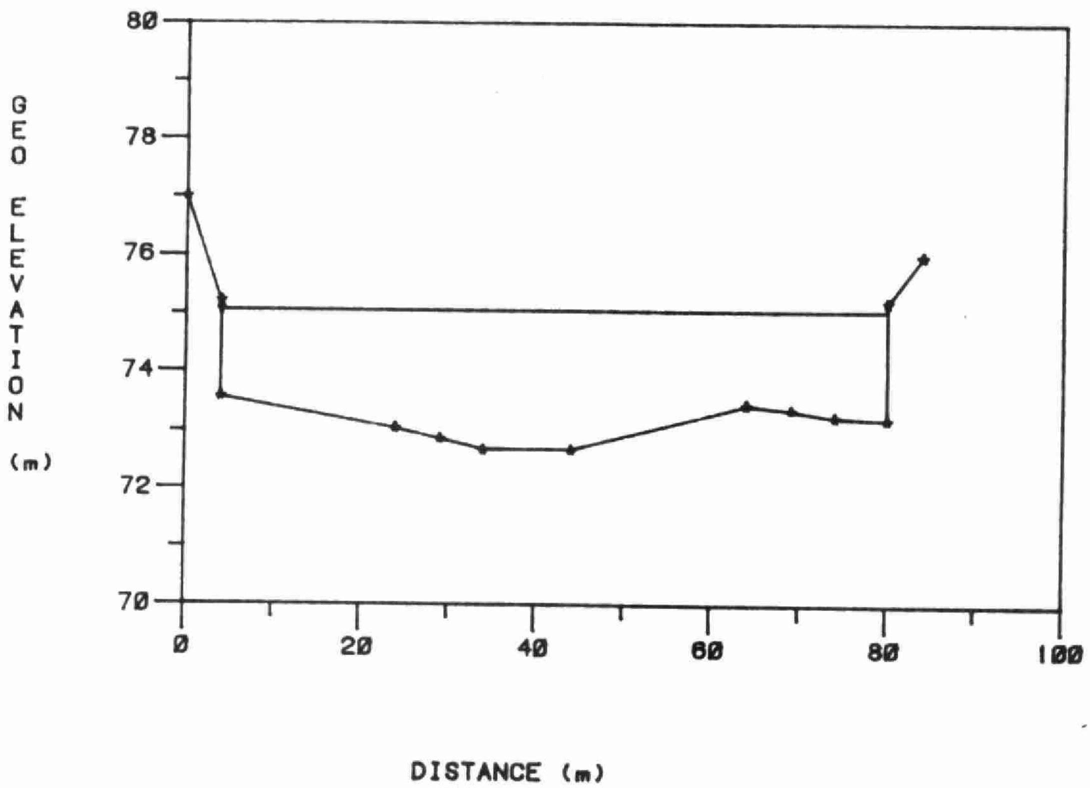

Figure A2

CROSS-SECTION #3

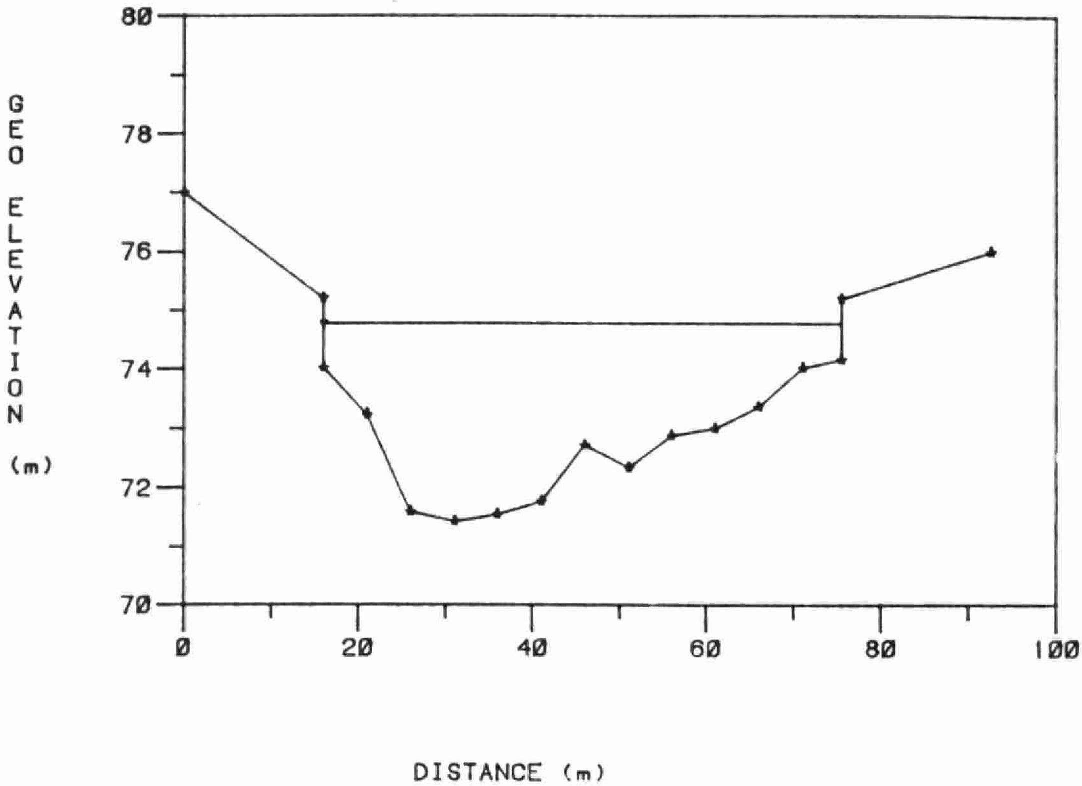

Figure A3

CROSS-SECTION #4

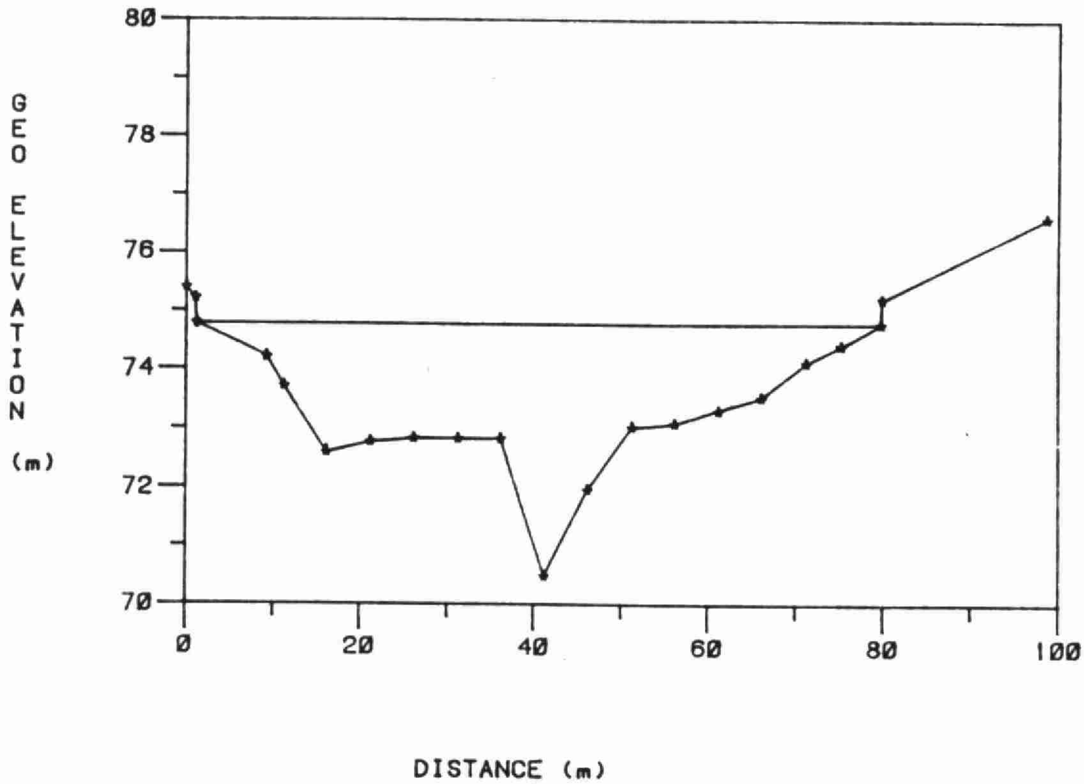

Figure A4

CROSS-SECTION #5

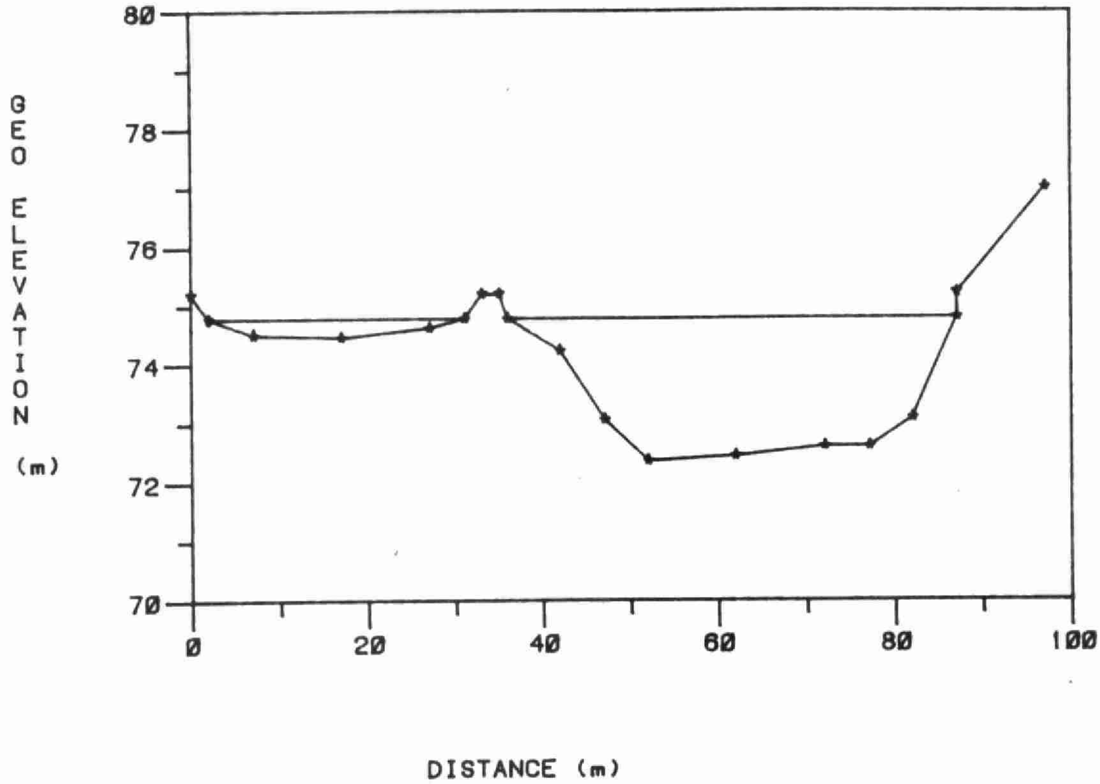

Figure A5

CROSS-SECTION #6

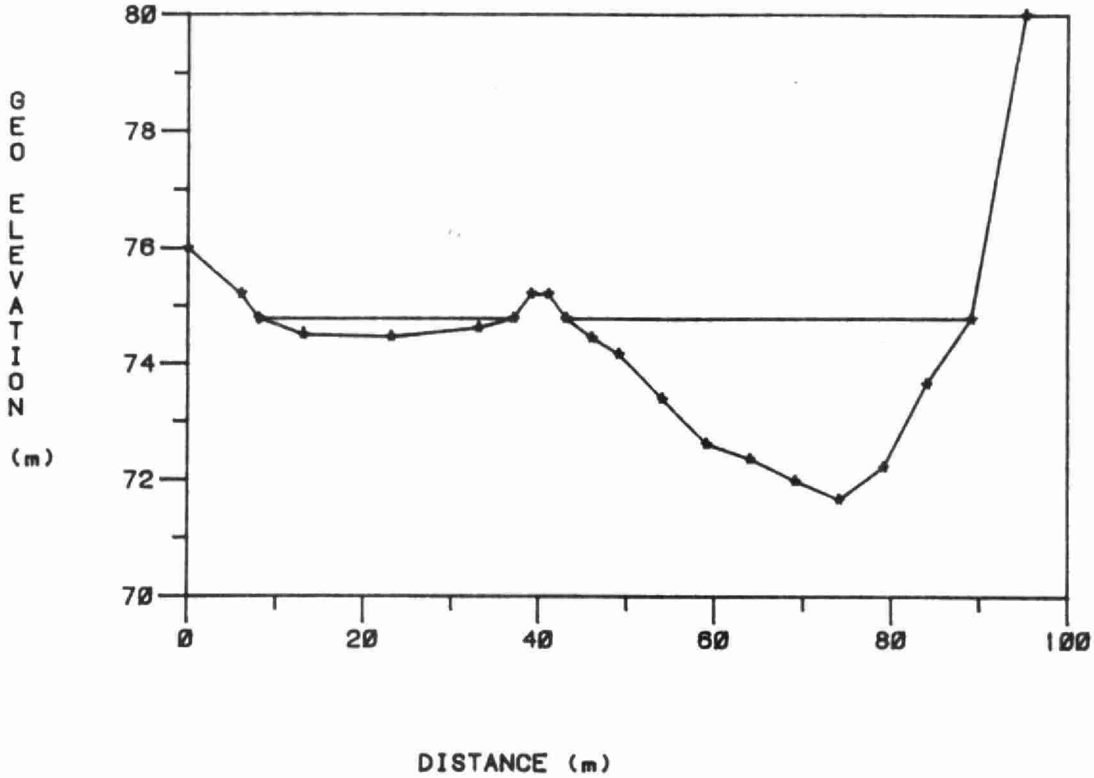

Figure A6

CROSS-SECTION #7

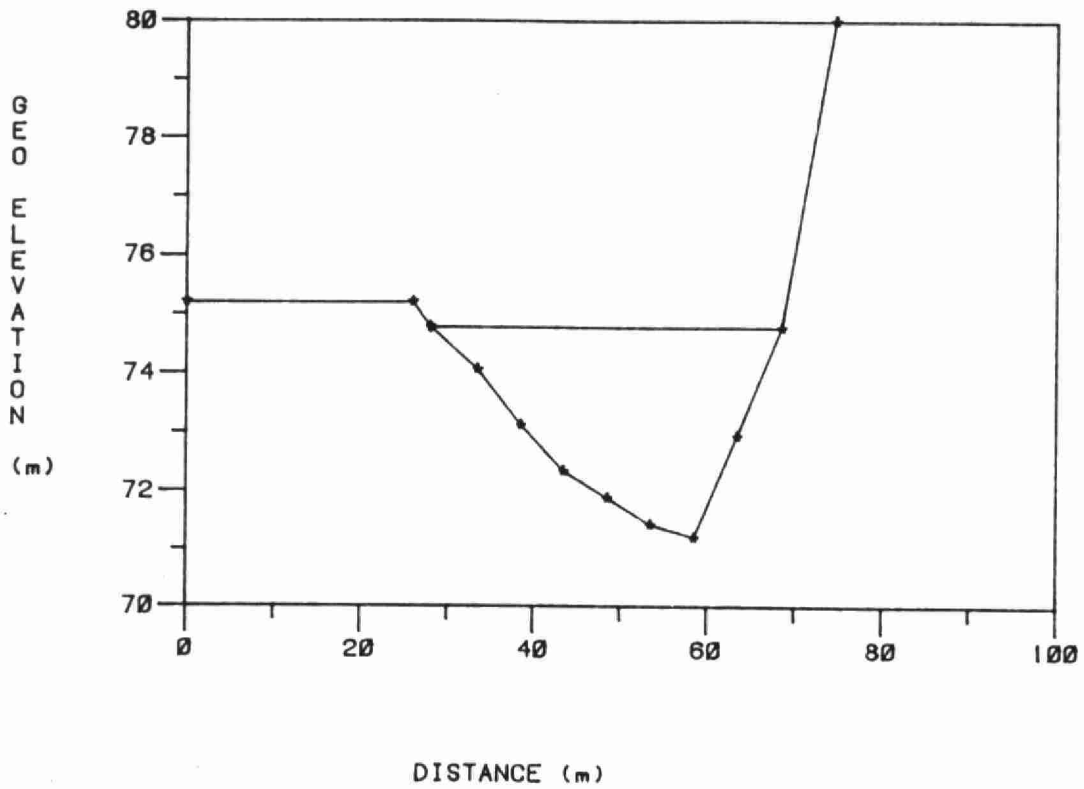

Figure A7

CROSS-SECTION #8

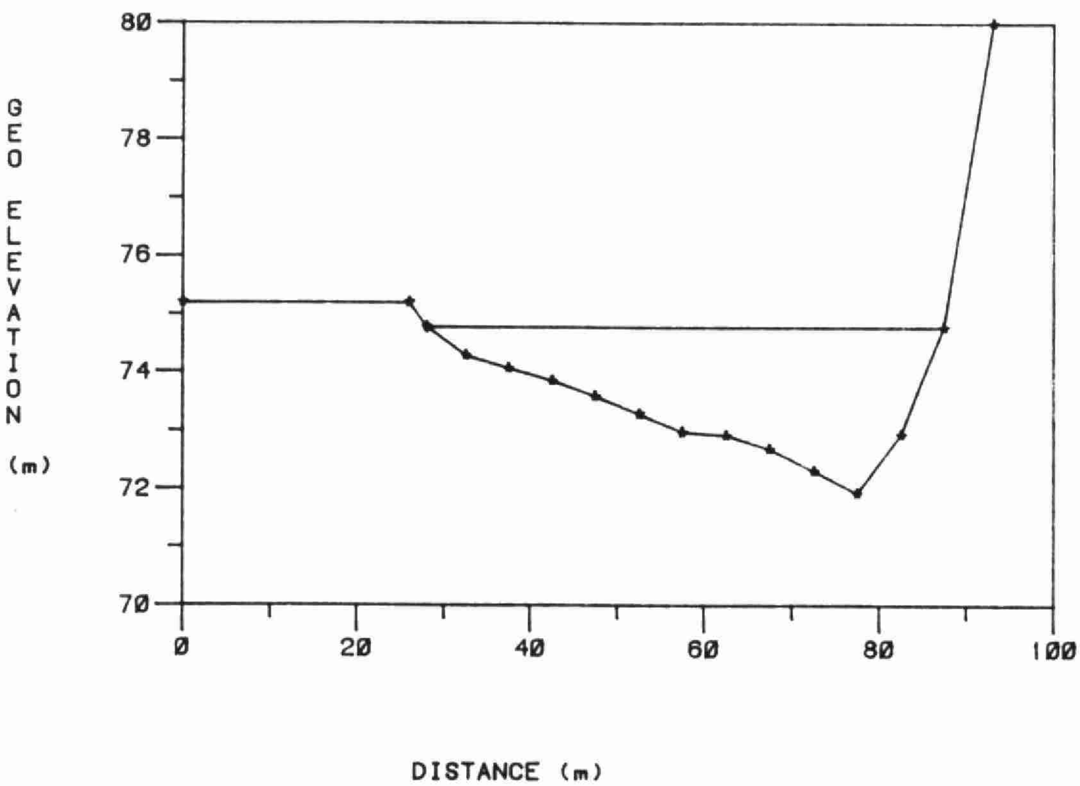

Figure A8

CROSS-SECTION #9

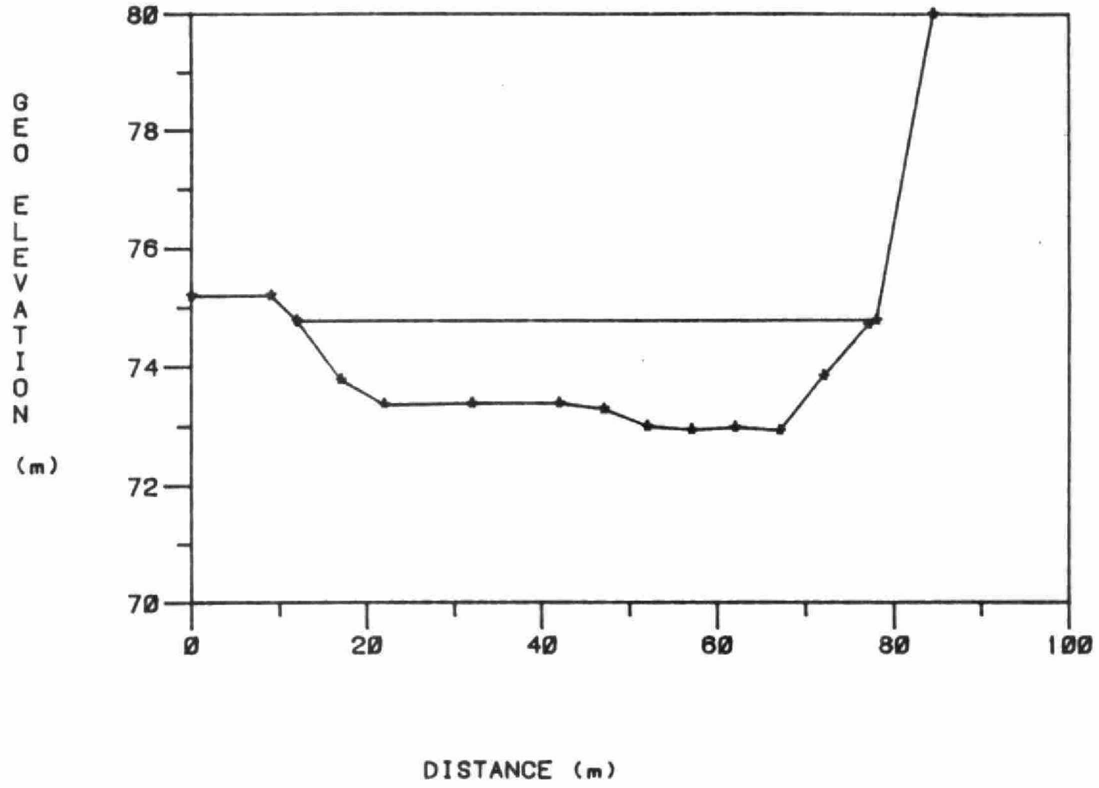

Figure A9

CROSS-SECTION #10

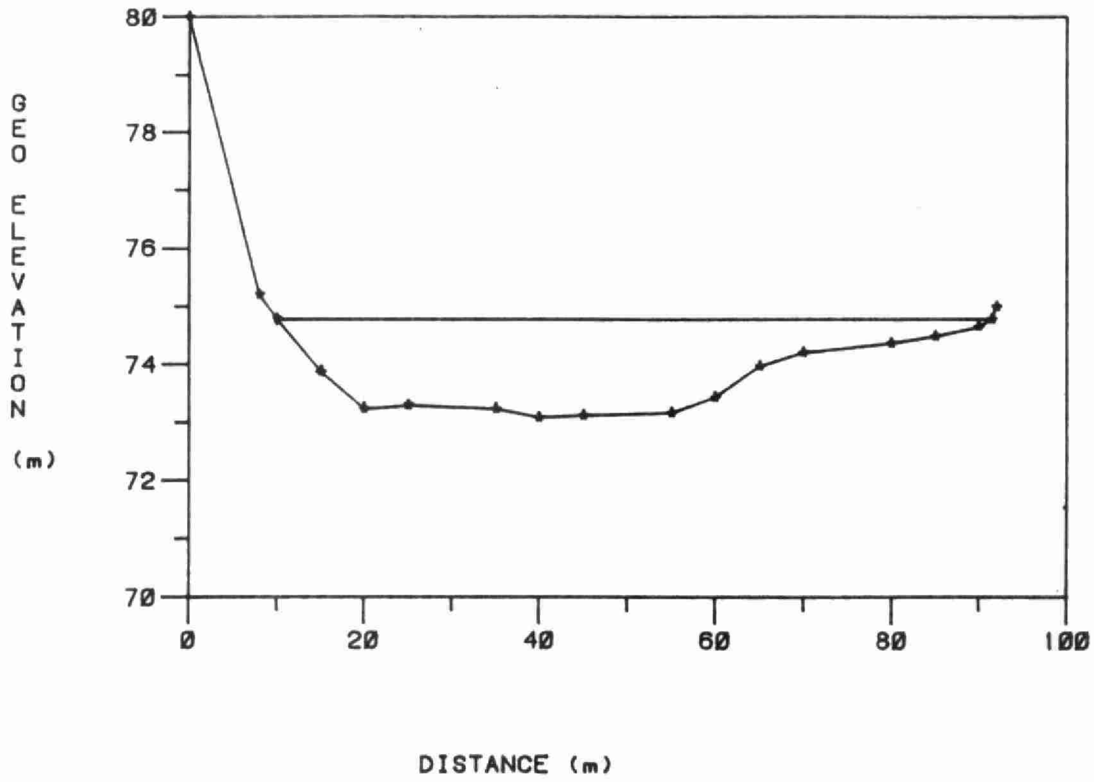

Figure A10

CROSS-SECTION #11

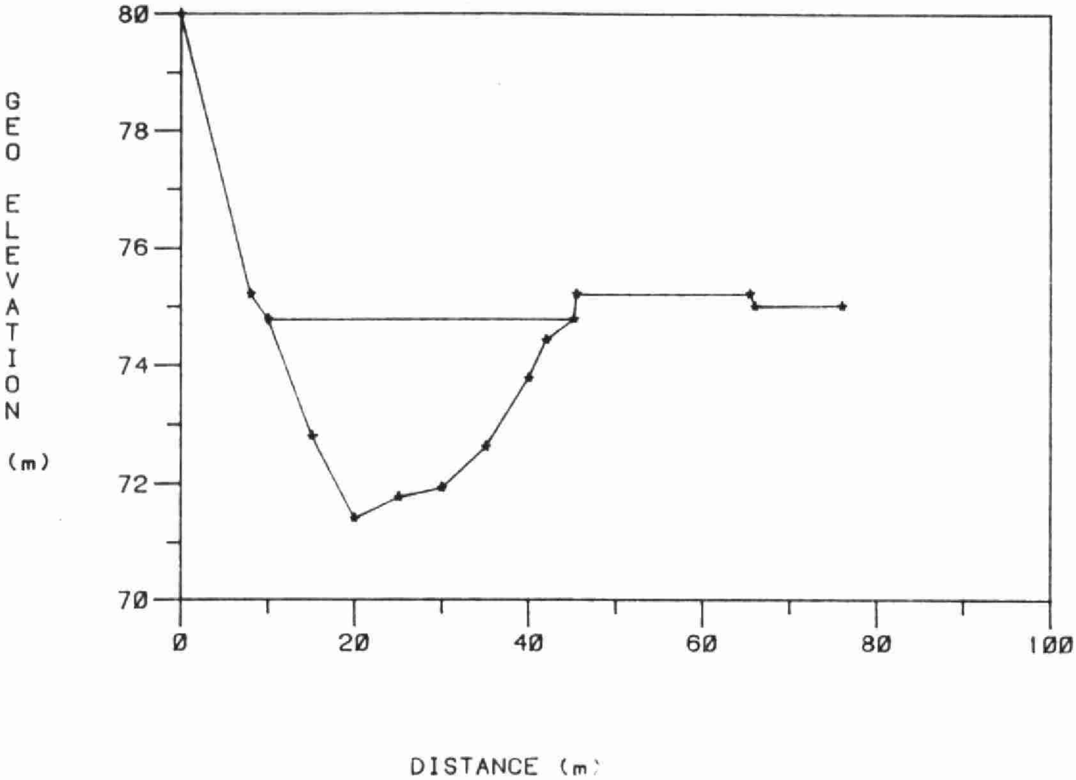

Figure A11

CROSS-SECTION #12

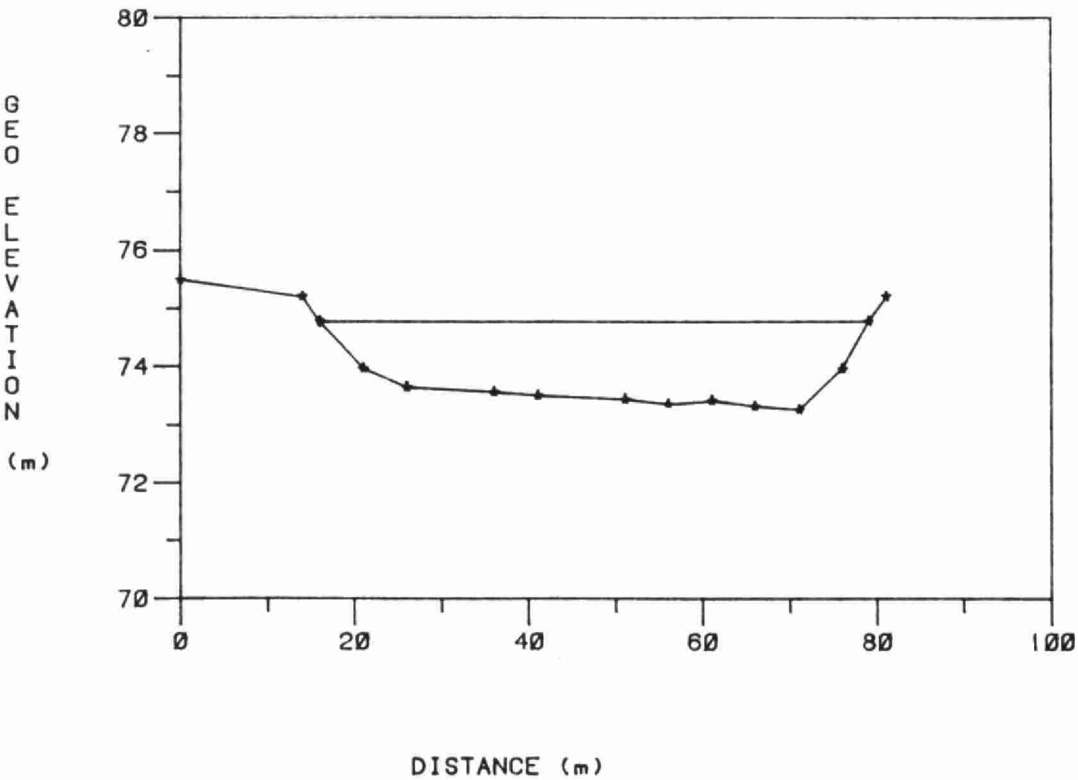

Figure A12

CROSS-SECTION #13

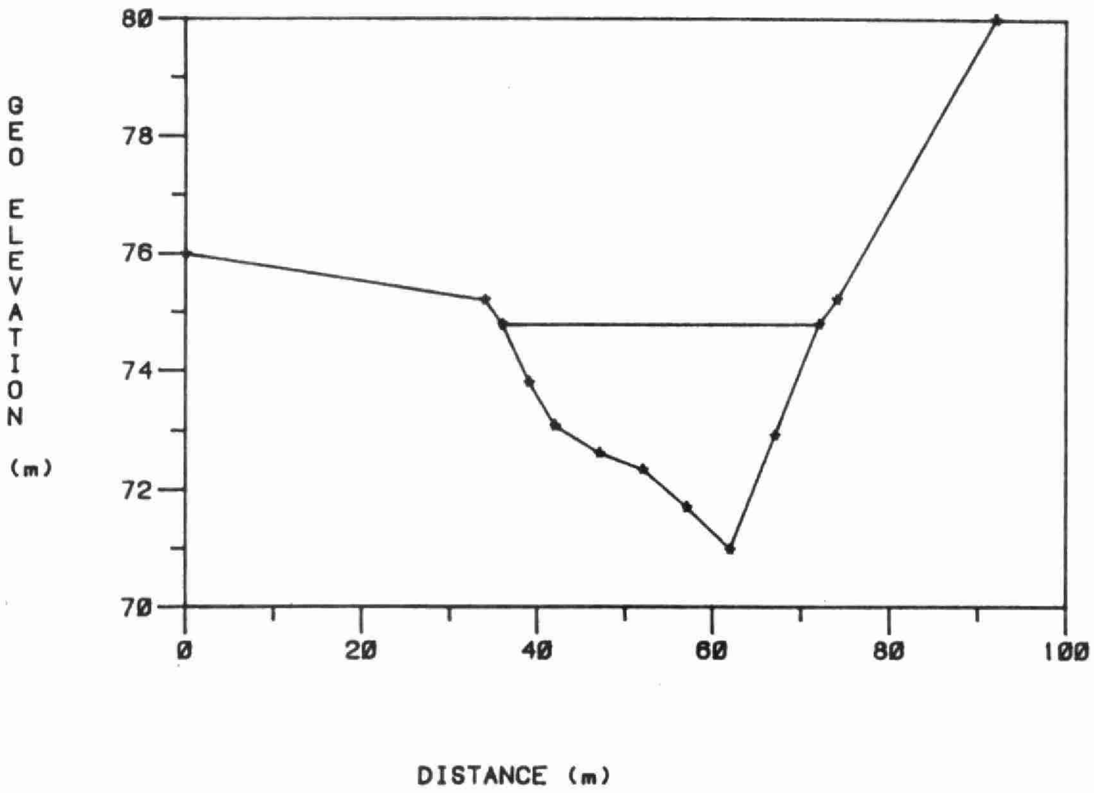

Figure A13

CROSS-SECTION #14

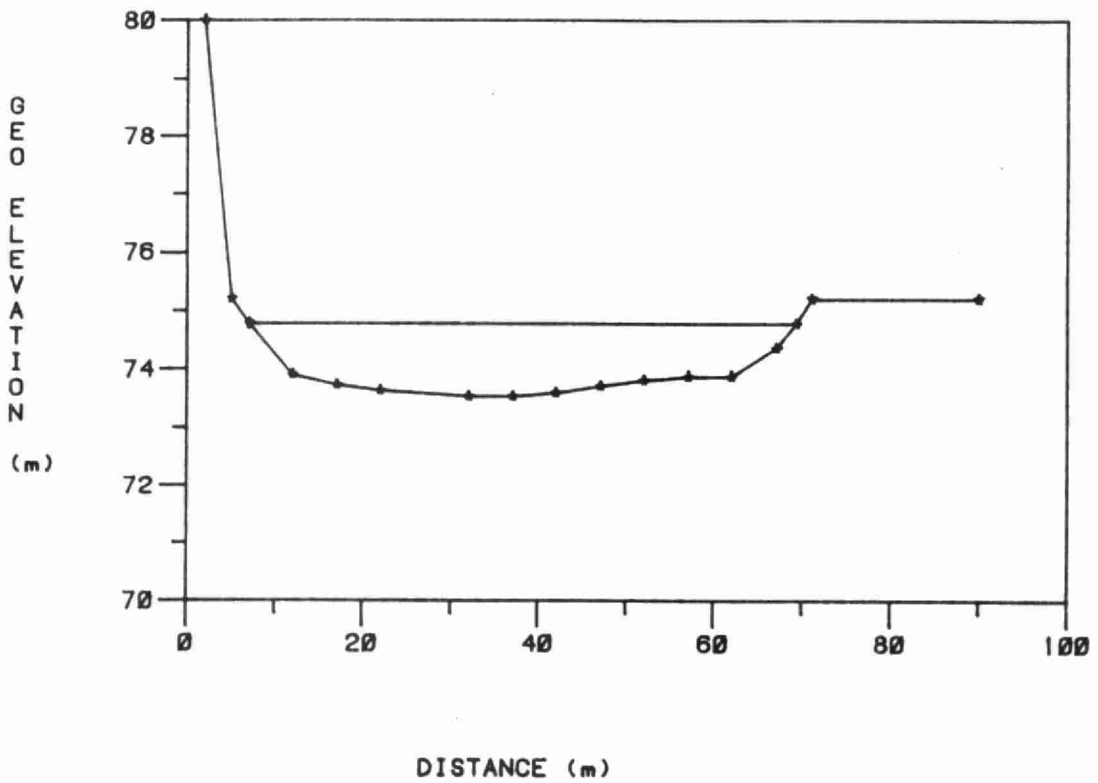

Figure A14

CROSS-SECTION #15

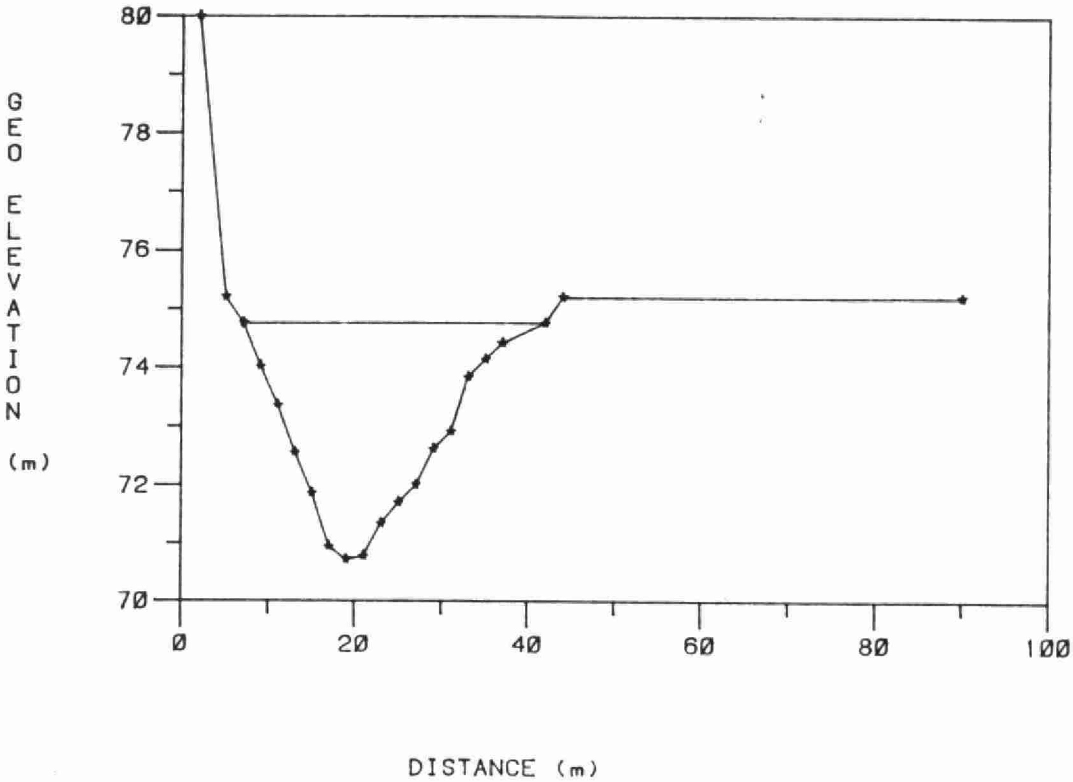

Figure A15

CROSS-SECTION #16

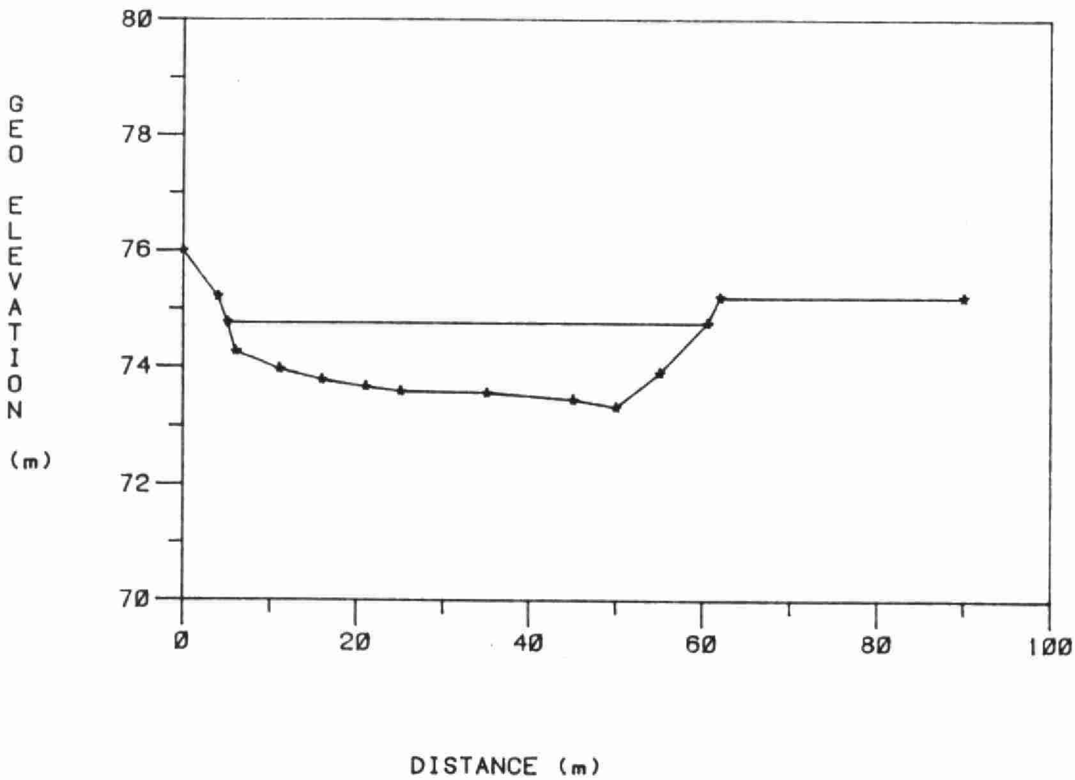

Figure A16

CROSS-SECTION #17

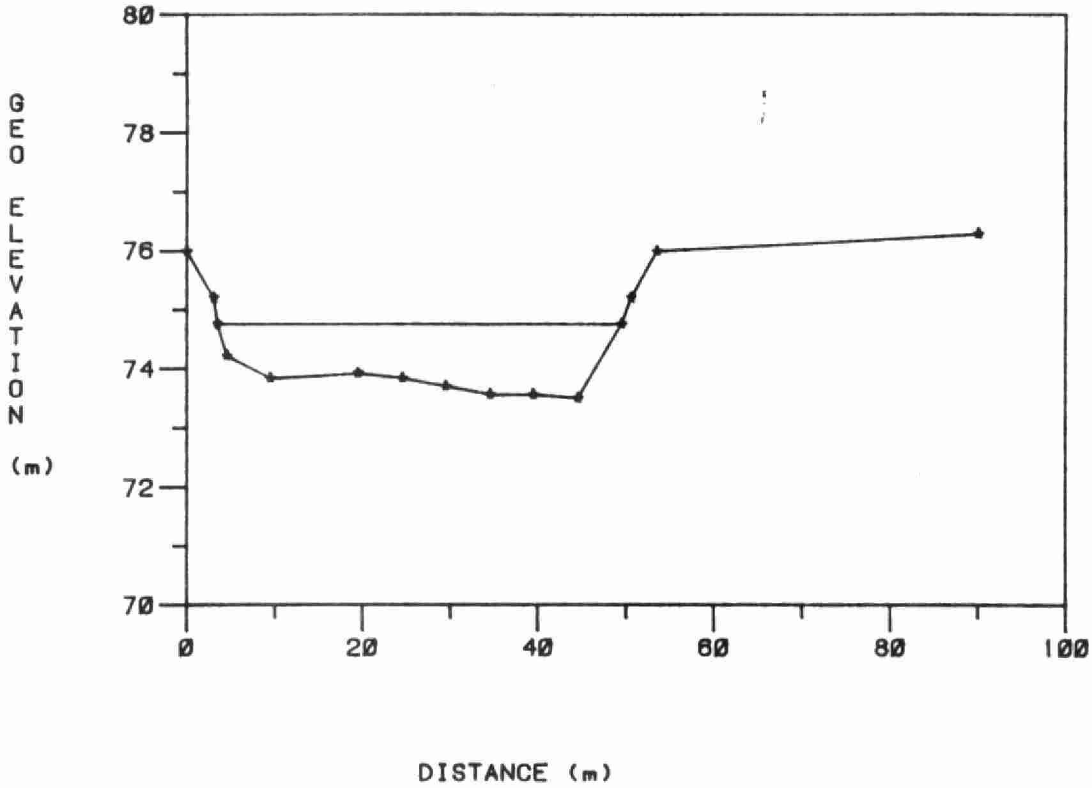

Figure A17

CROSS-SECTION #18

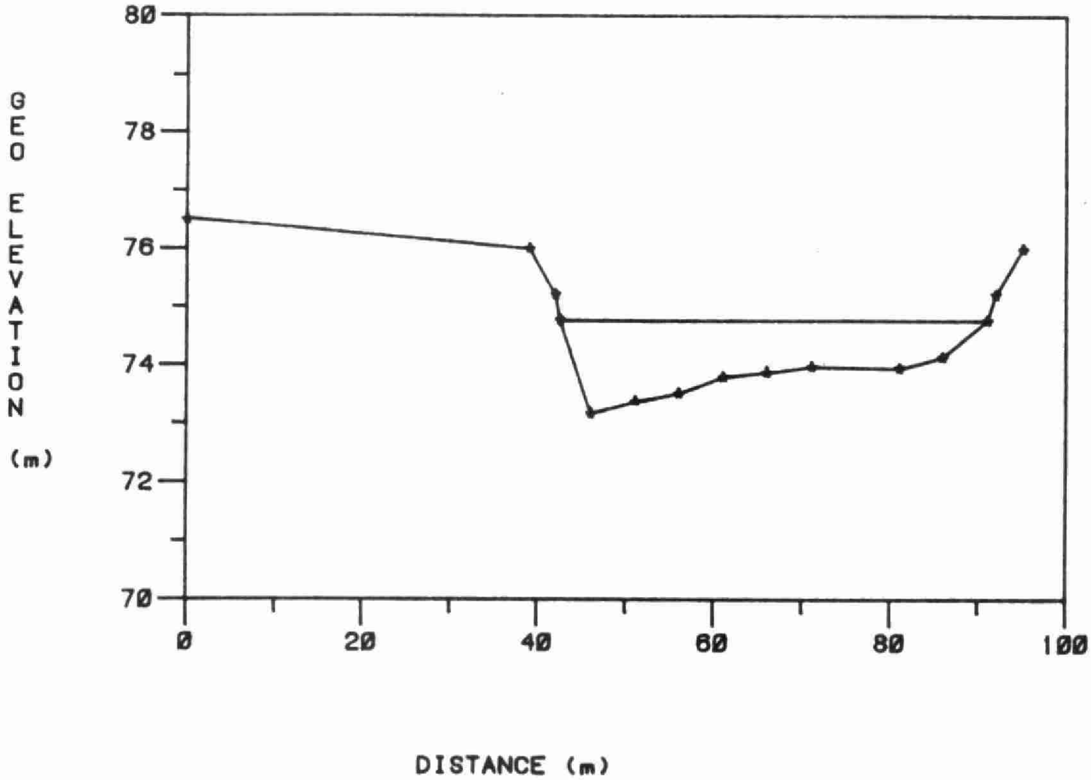

Figure A18

CROSS-SECTION #19

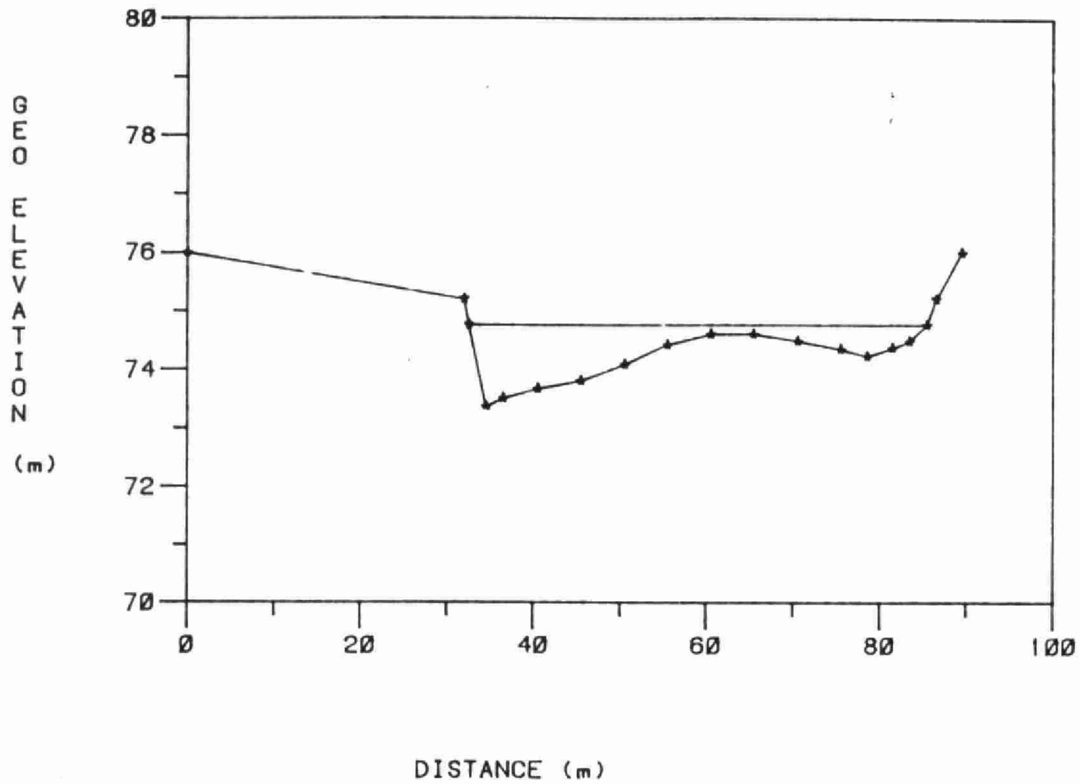

Figure A19

CROSS-SECTION #20

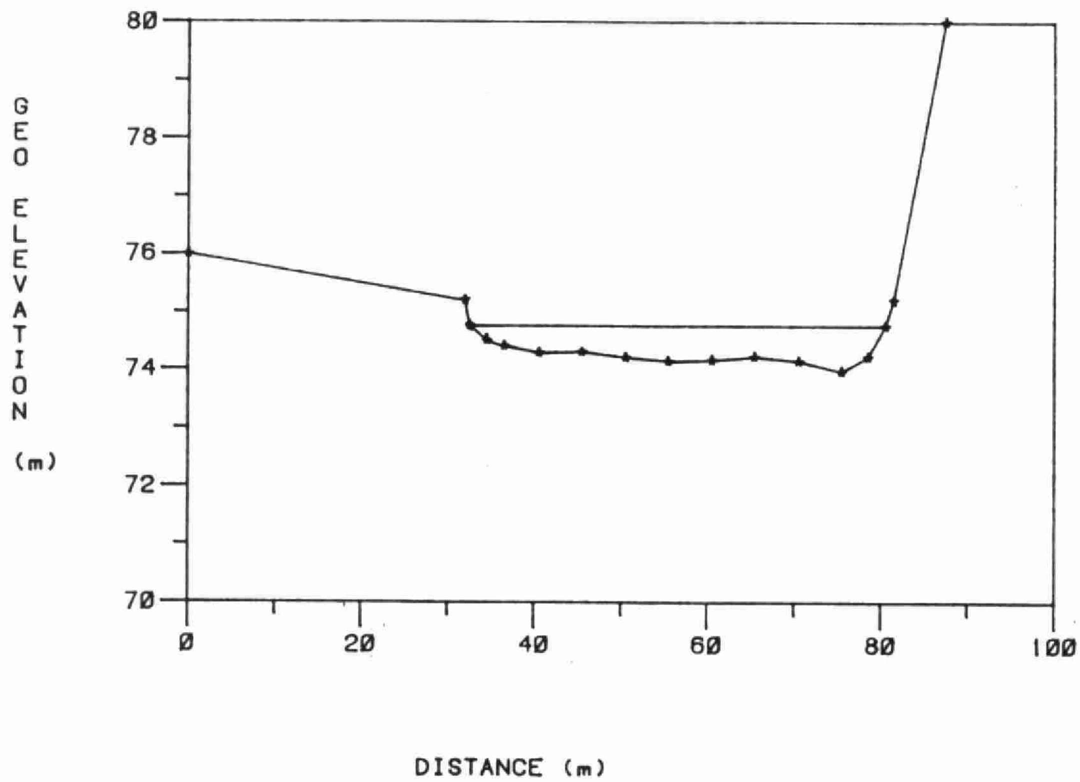

Figure A20

APPENDIX B

Channel Cross-sectional Plots - Humber River
- Bloor Street to Steeles Avenue

HUMBER D/S OF BLACK CREEK - 100 M D/S OF CONFLUENCE.

CROSS-SECTION # 2

BEARING 123 MAGNETIC

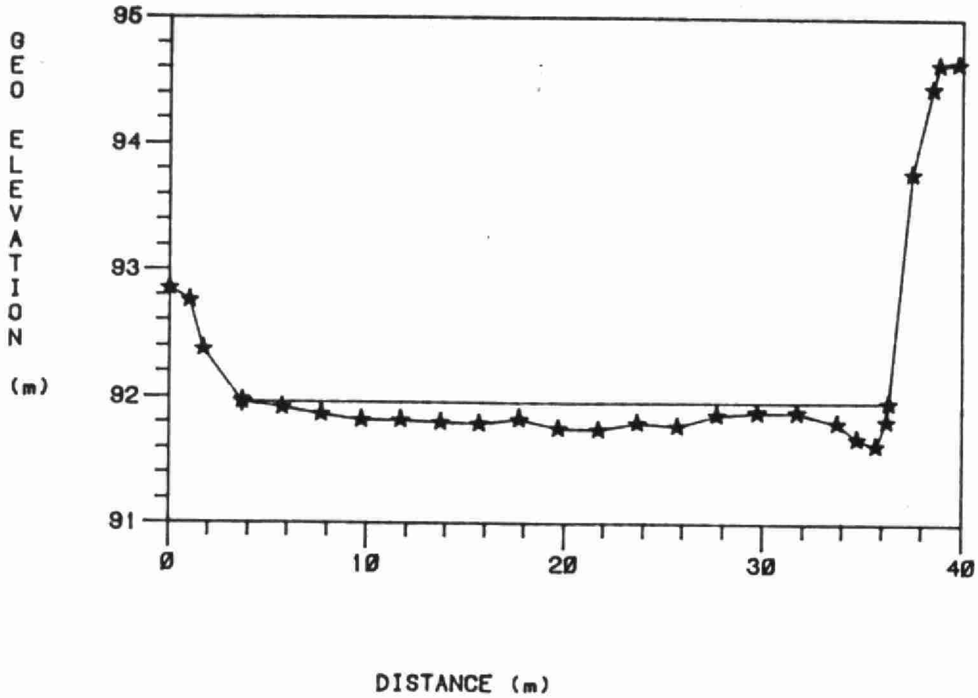

Figure B1

HUMBER U/S OF SILVER CREEK - 20 M U/S OF CONFLUENCE.

CROSS-SECTION # 3

BEARING 155 MAGNETIC

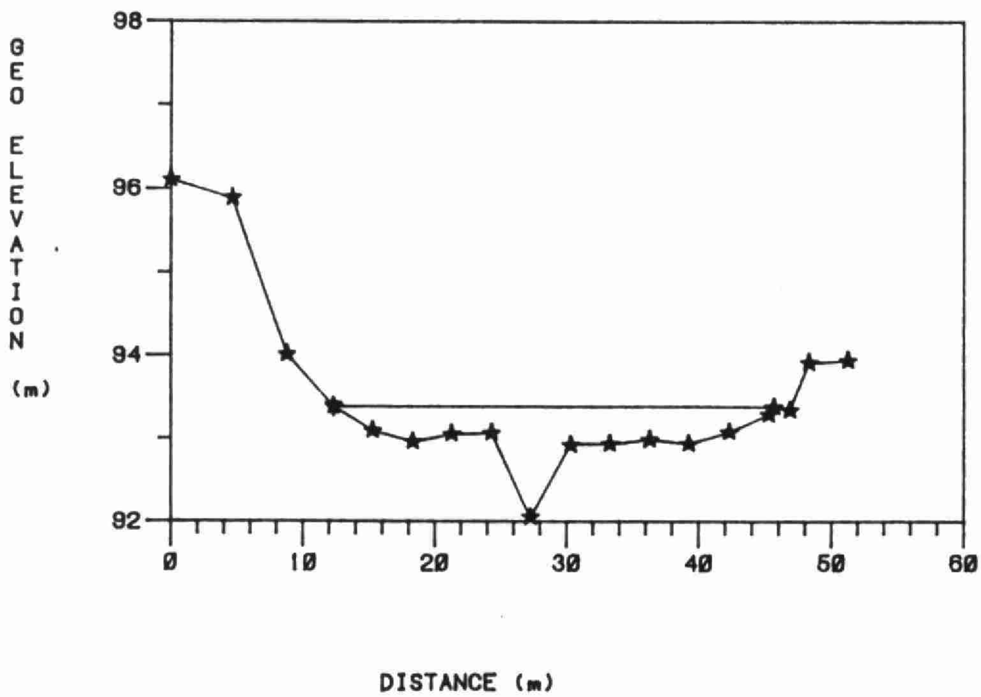

Figure B2

HUMBER D/S OF HUMBER CREEK - 55 M D/S OF CONFLUENCE.

CROSS-SECTION # 4

BEARING 102 MAGNETIC

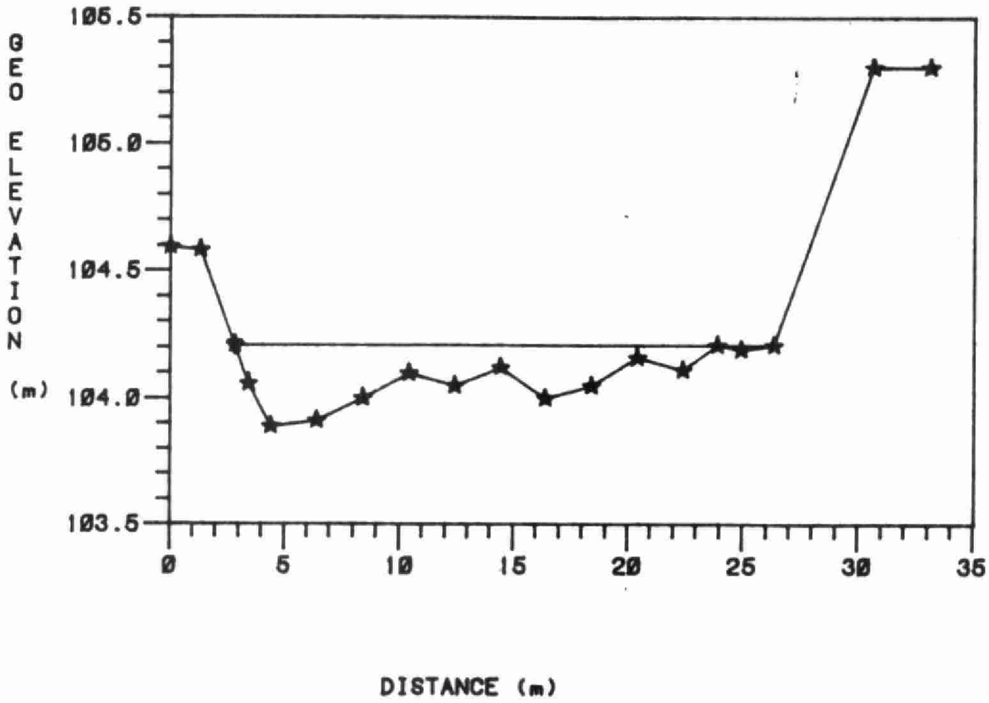

Figure B3

HUMBER AT ALBION RD. - 10 M U/S OF ALBION RD. BRIDGE

CROSS-SECTION #6

BEARING 127 MAGNETIC

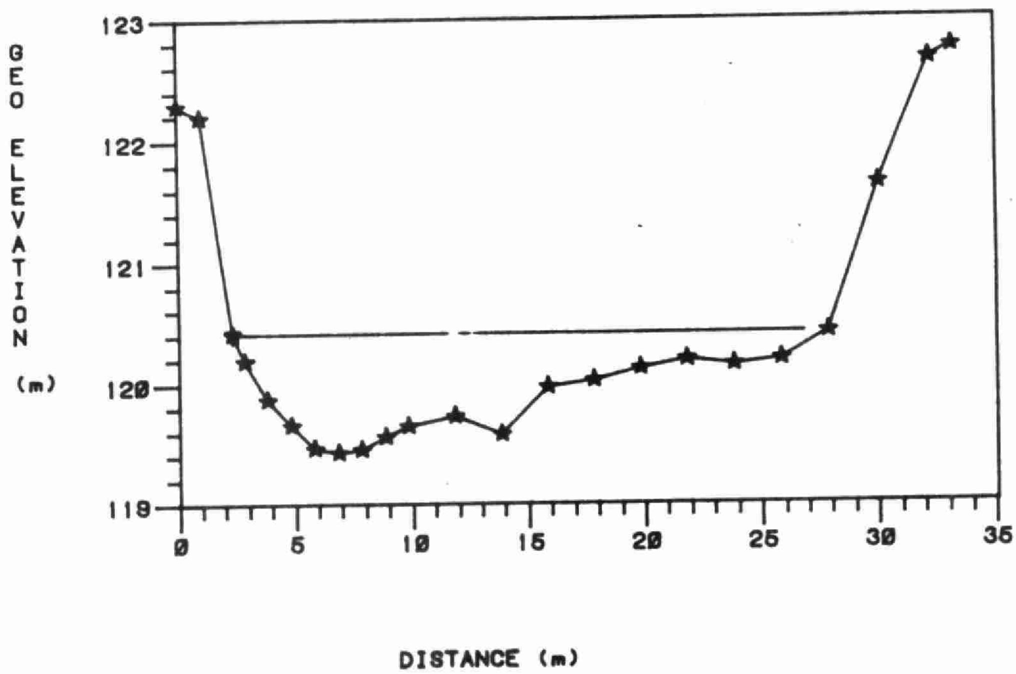

Figure B4

HUMBER UPSTREAM OF EMERY CREEK - 125 M U/S OF CONFLUENCE.

CROSS-SECTION #11

BEARING 62 MAGNETIC

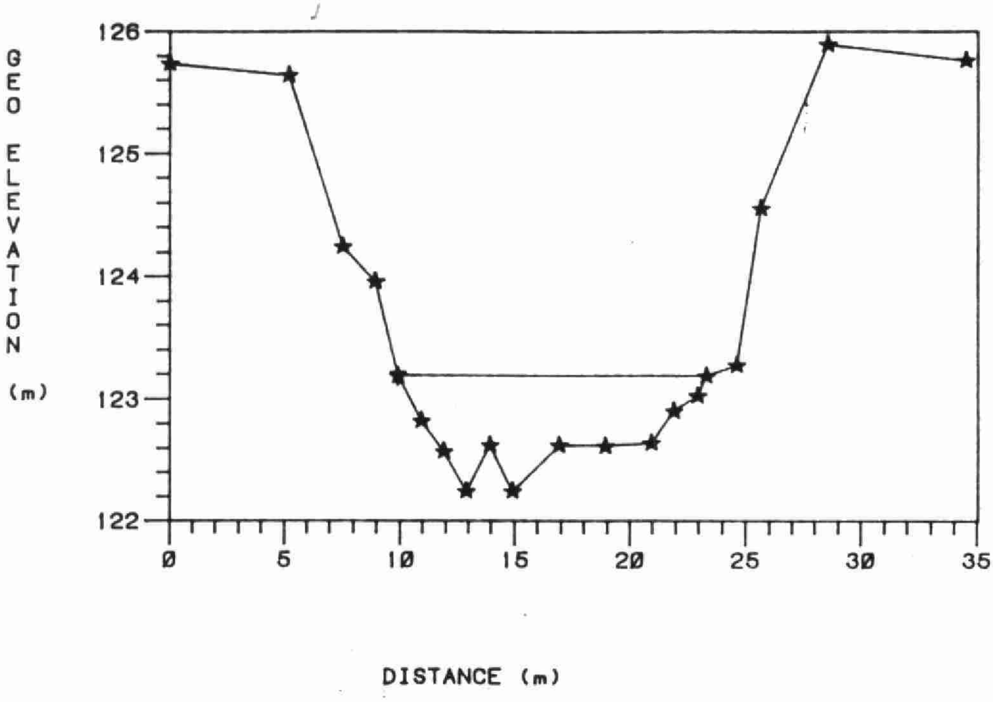

Figure B5

HUMBER AT ROWNTREE MILL RD.- 22.7 M U/S OF BRIDGE OVER HUMBER.

CROSS-SECTION #12

BEARING 217 MAGNETIC

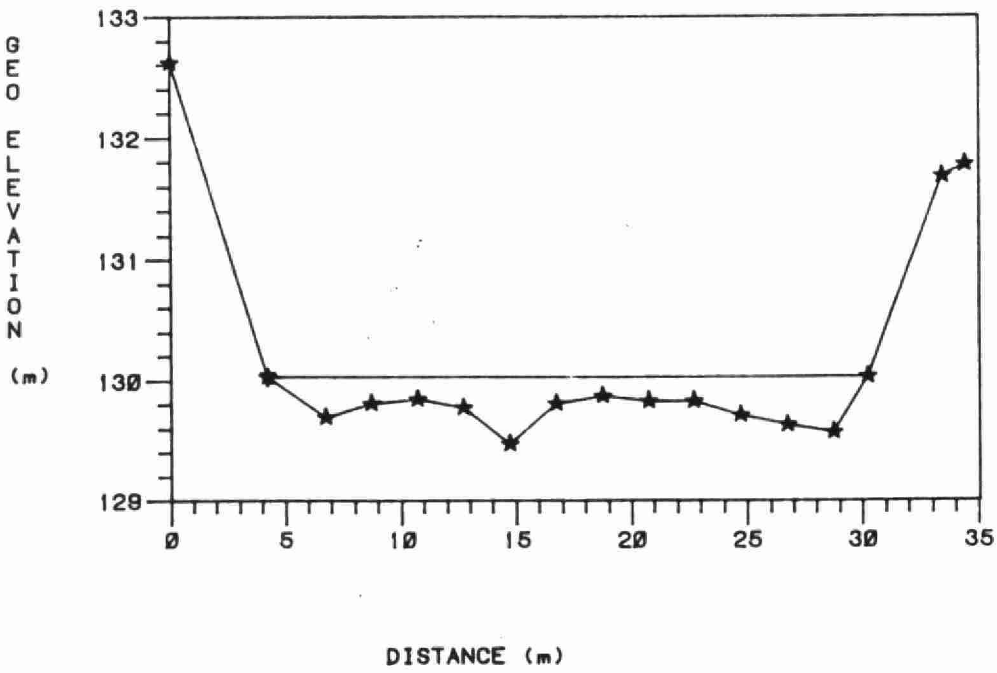

Figure B6

APPENDIX C

Channel Cross-sectional Plots - Humber River
- Above Steeles Avenue
- Humber River Tributaries

HUMBER CREEK SOURCE - 101 M D/S OF CULVERT AT WINCOTT DR.

CROSS-SECTION #5A

BEARING 127 MAGNETIC

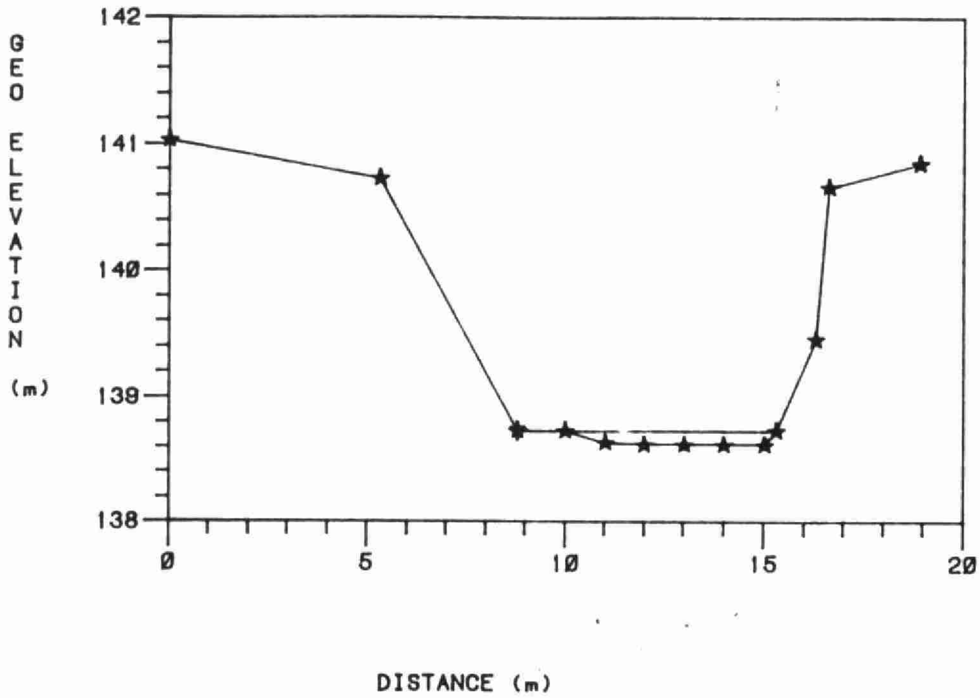

Figure C1

HUMBER CREEK AT MAIN HUMBER - 31 M U/S OF SCARLETT RD. BRIDGE

CROSS-SECTION #5B

BEARING 2 MAGNETIC

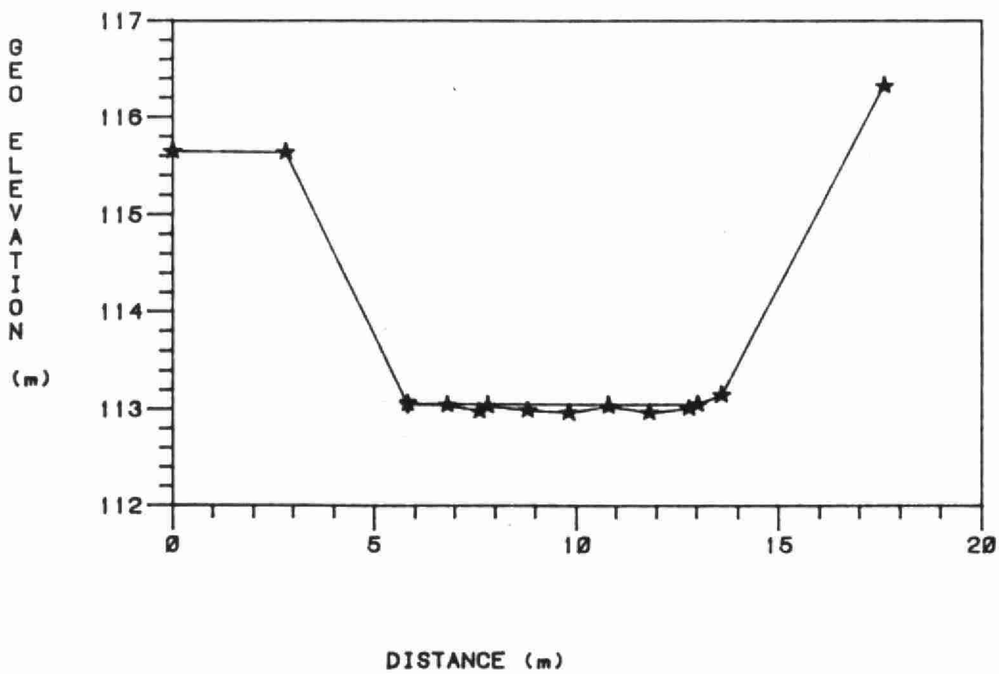

Figure C2

WEST HUMBER U/S OF ALBION CREEK - 55 M U/S OF CONFLUENCE

CROSS-SECTION #7

BEARING 191 MAGNETIC

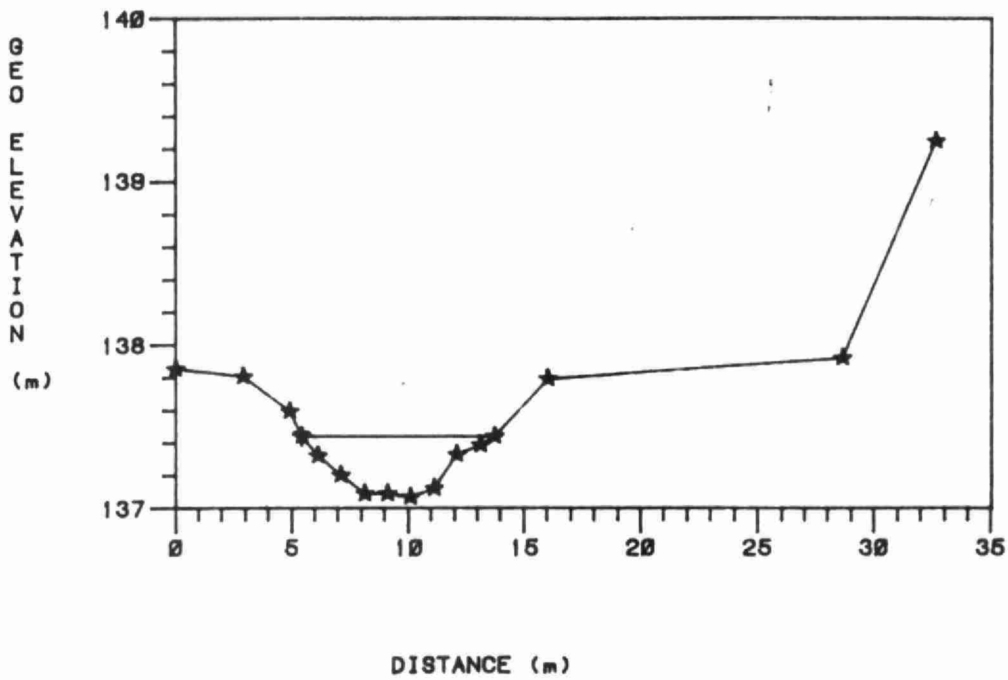

Figure C3

WEST HUMBER AT MARTIN GROVE RD. - 21 M U/S OF BRIDGE

CROSS-SECTION #8

BEARING 148 MAGNETIC

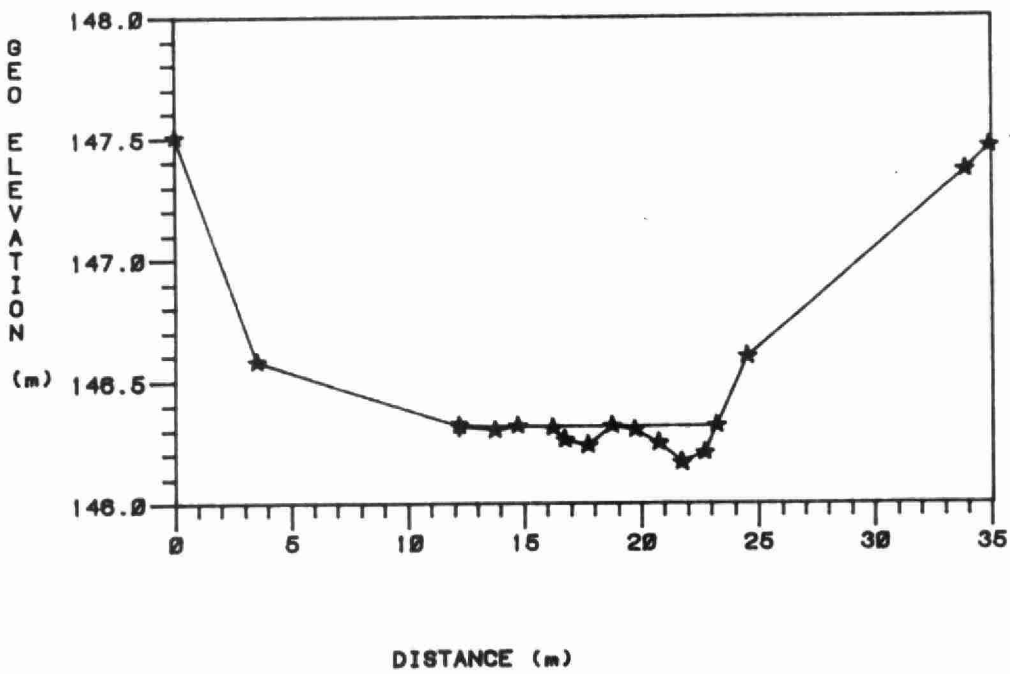

Figure C4

WEST HUMBER AT HUMBERLINE DR. - 200 M NORTH OF REXDALE BLVD.

CROSS-SECTION #9

BEARING 1 MAGNETIC

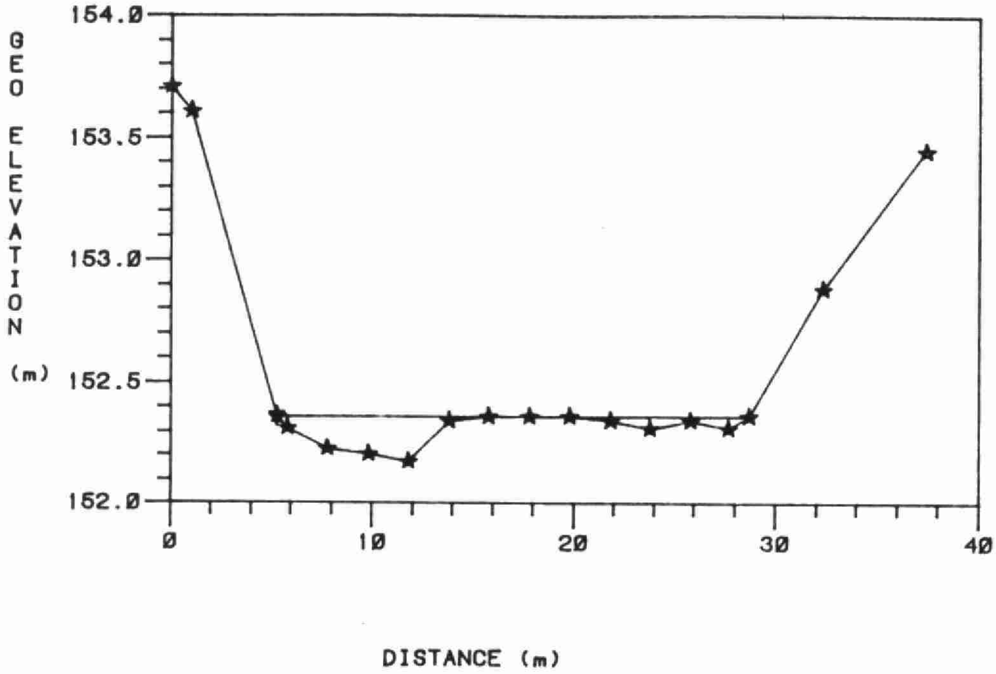

Figure C5

WEST HUMBER AT INDIAN LINE - 180 M D/S OF CLAIRVILLE DAM.

CROSS-SECTION #10

BEARING 7 MAGNETIC

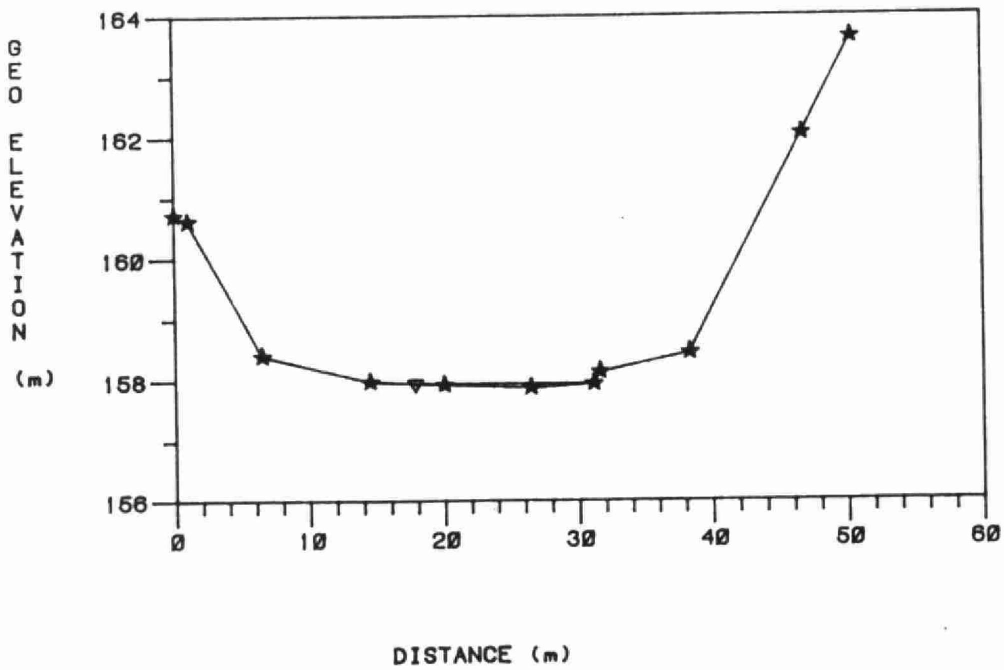

Figure C6

HUMBER D/S OF CONFLUENCE WITH EAST HUMBER-31 M D/S OF CONFLUENCE

CROSS-SECTION #13

BEARING 264 MAGNETIC

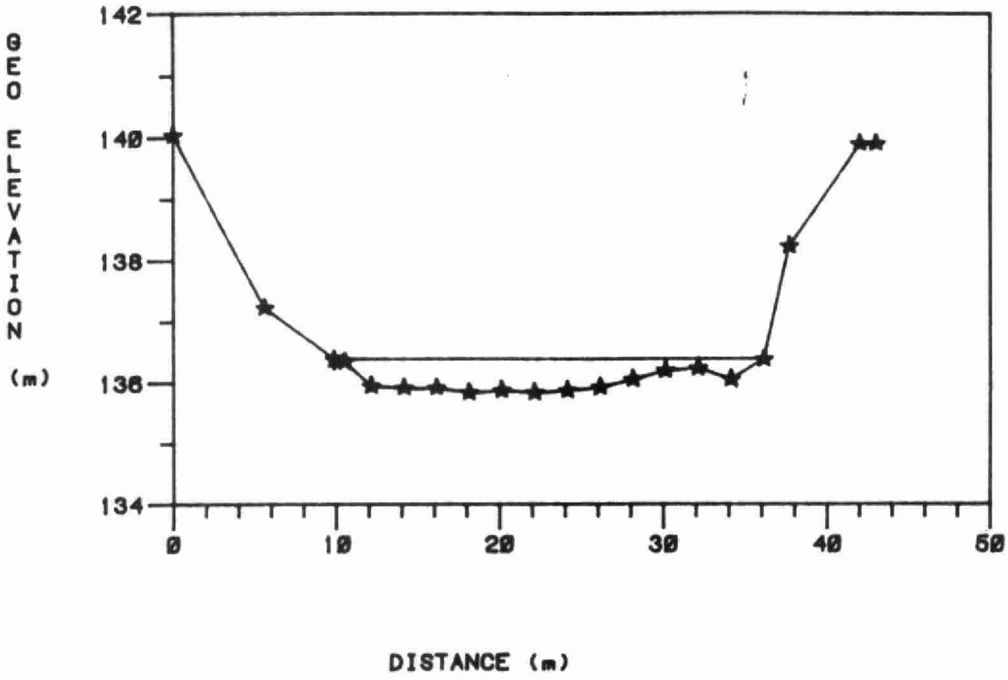

Figure C7

HUMBER AT RUTHERFORD RD. - 200 M D/S OF HWY 27 BRIDGE

CROSS-SECTION #14

BEARING 80 MAGNETIC

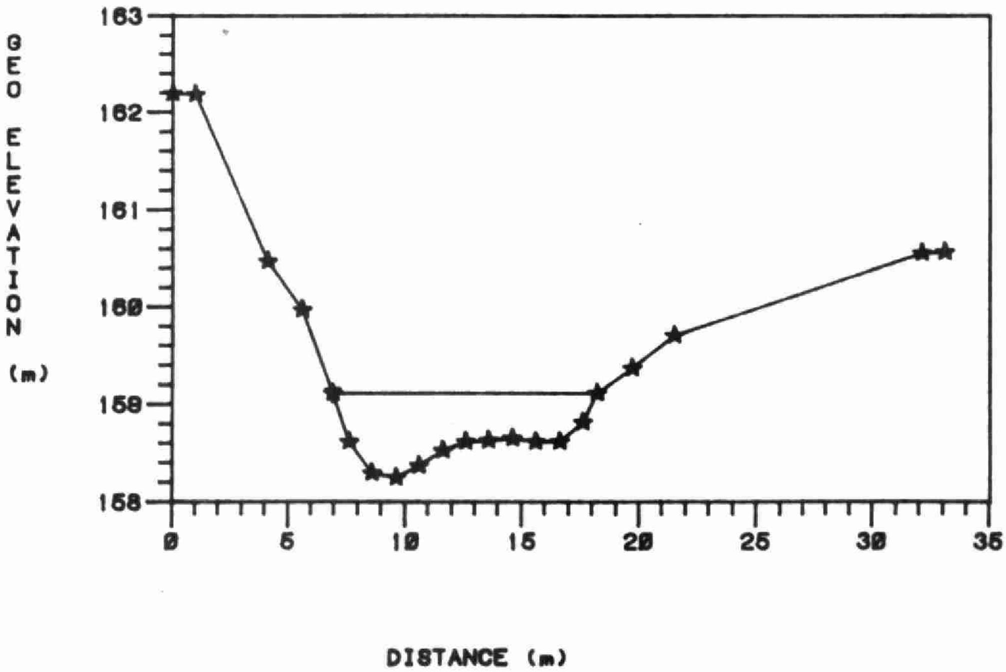

Figure C8

SOURCE OF CREEK BETWEEN MAIN & WEST HUMBERS - 35 M D/S OF CONFLUENCE

CROSS-SECTION #15A

BEARING 72 MAGNETIC

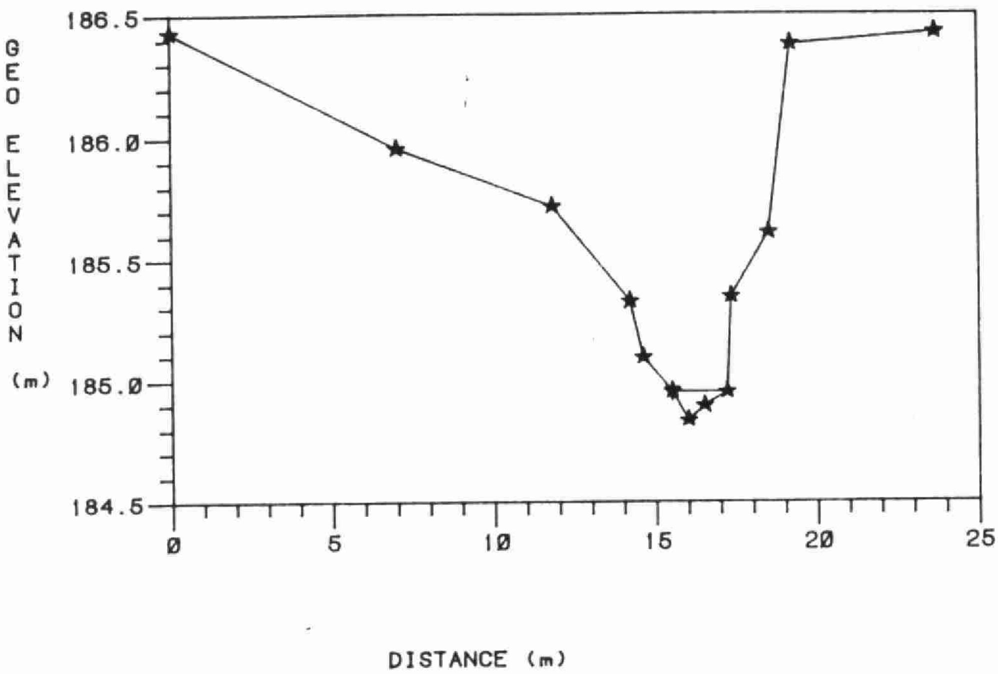

Figure C9

CONFLUENCE OF CREEK BETWEEN MAIN & WEST HUMBERS & MAIN HUMBER-20 M U/S

CROSS-SECTION #15B

BEARING 345 MAGNETIC

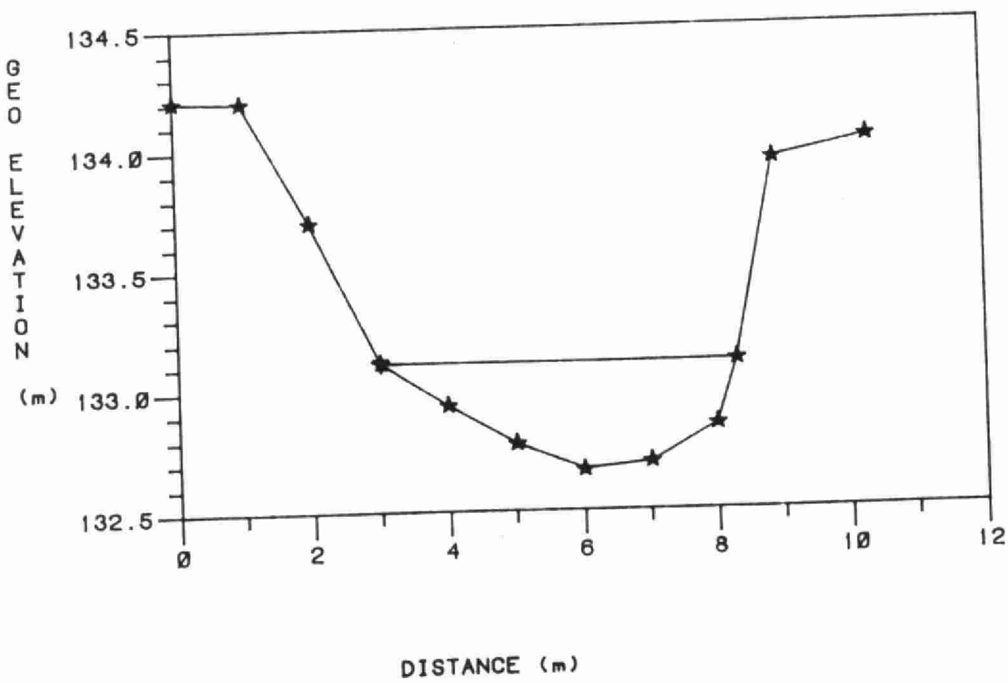

Figure C10

APPENDIX D

Topographic Maps of Sediment Deposition
- Zones 22,23,27-30,32,34-36,38-44

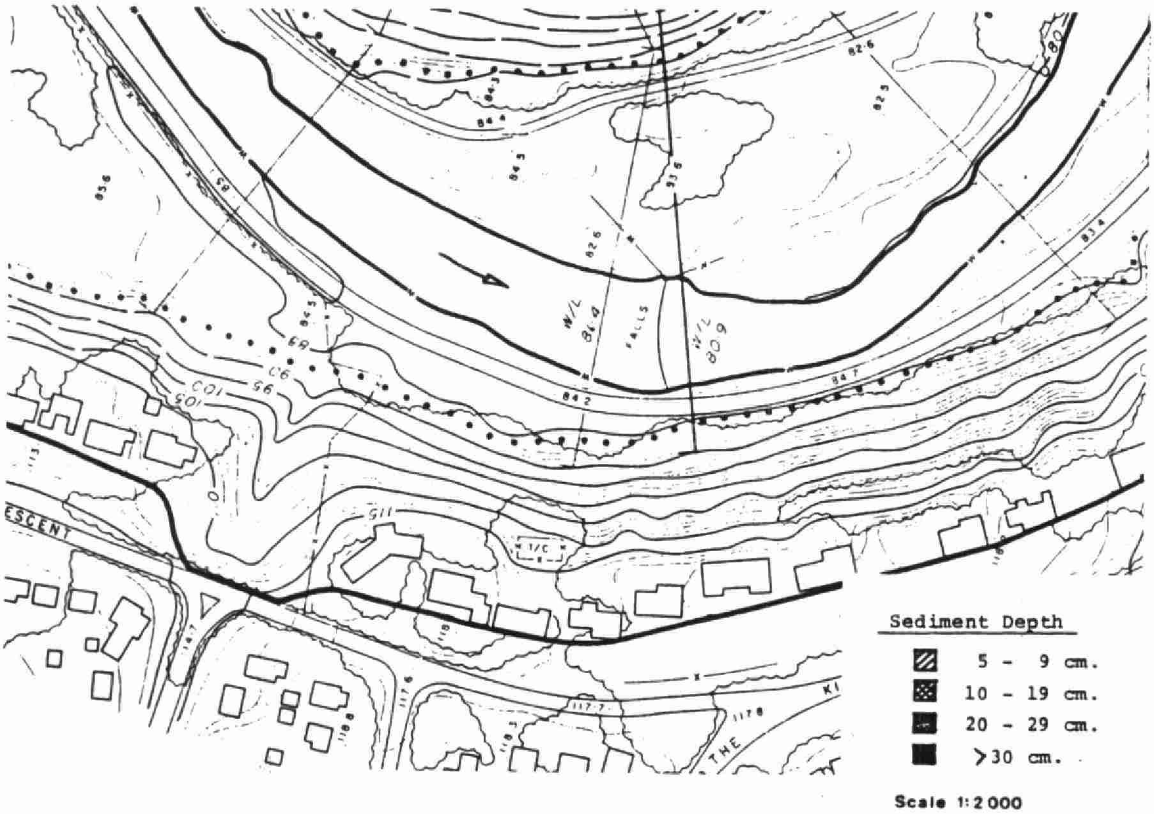

Figure D1 Topographic Map of Sediment Deposition - Zone # 22

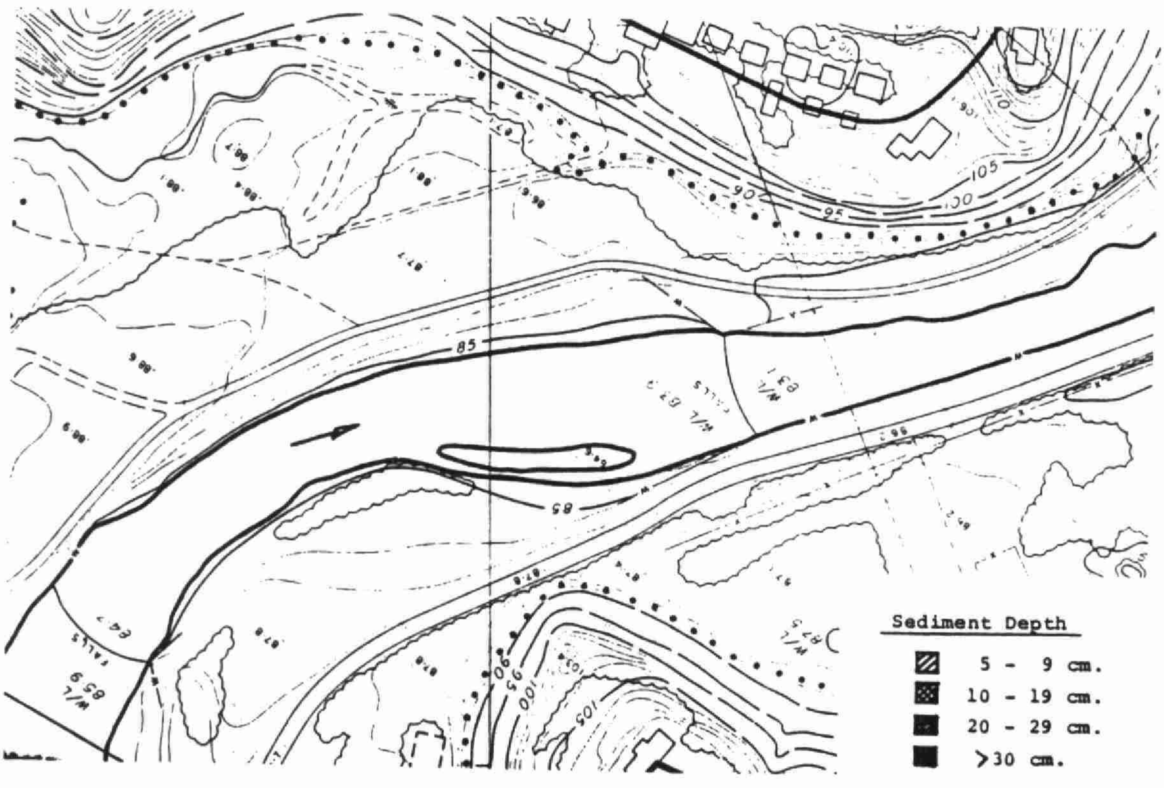

Figure D2 Topographic Map of Sediment Deposition - Zone # 23

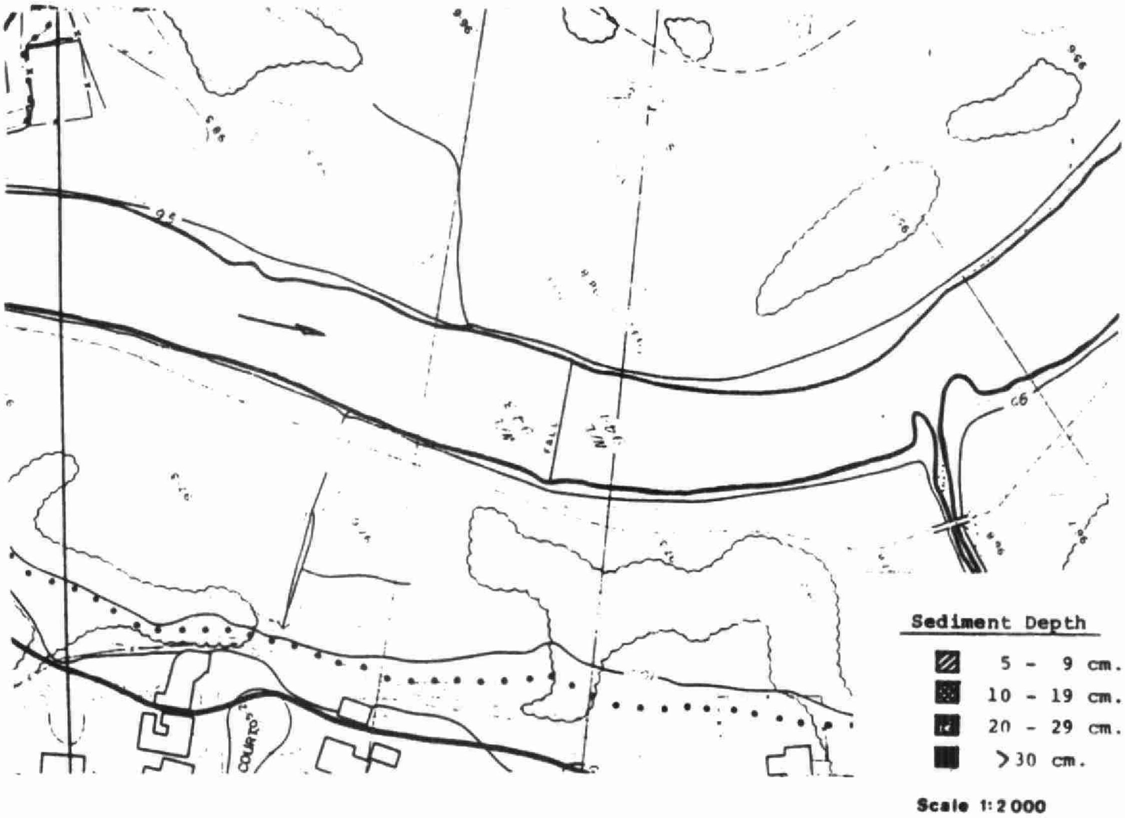

Figure D3 Topographic Map of Sediment Deposition - Zone # 27

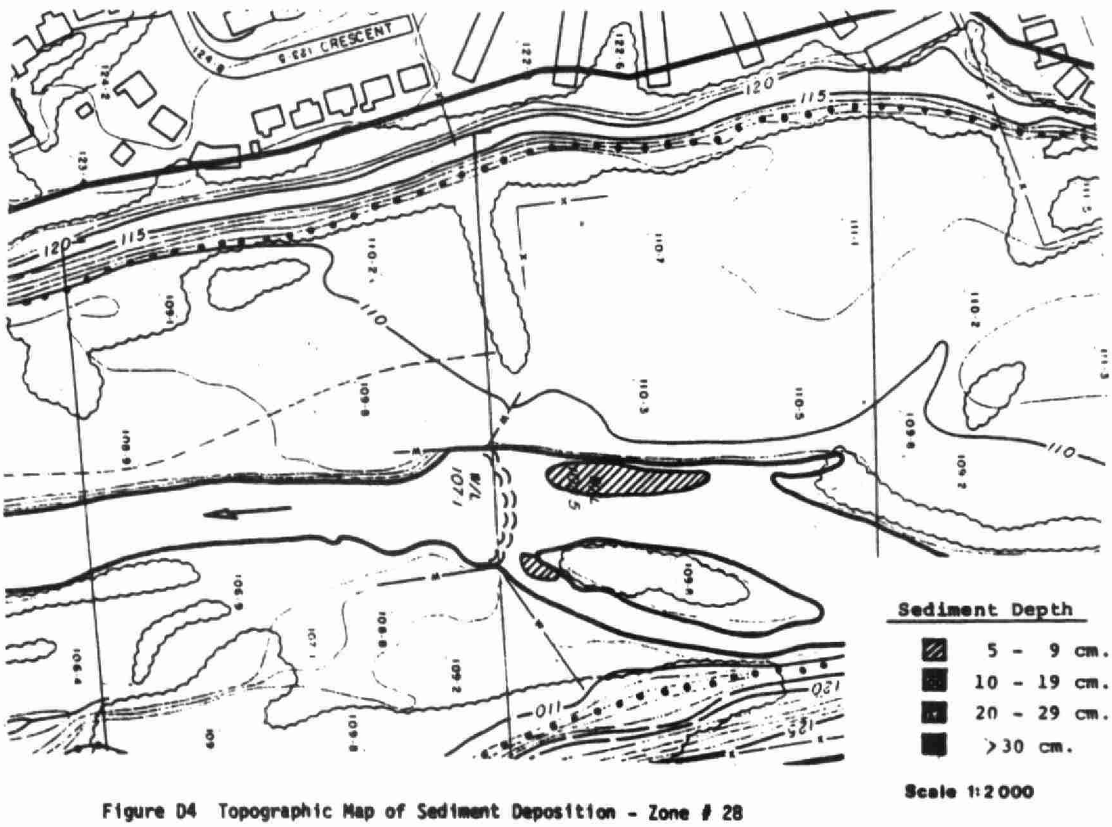

Figure D4 Topographic Map of Sediment Deposition - Zone # 28

Figure D5 Topographic Map of Sediment Deposition - Zone # 29

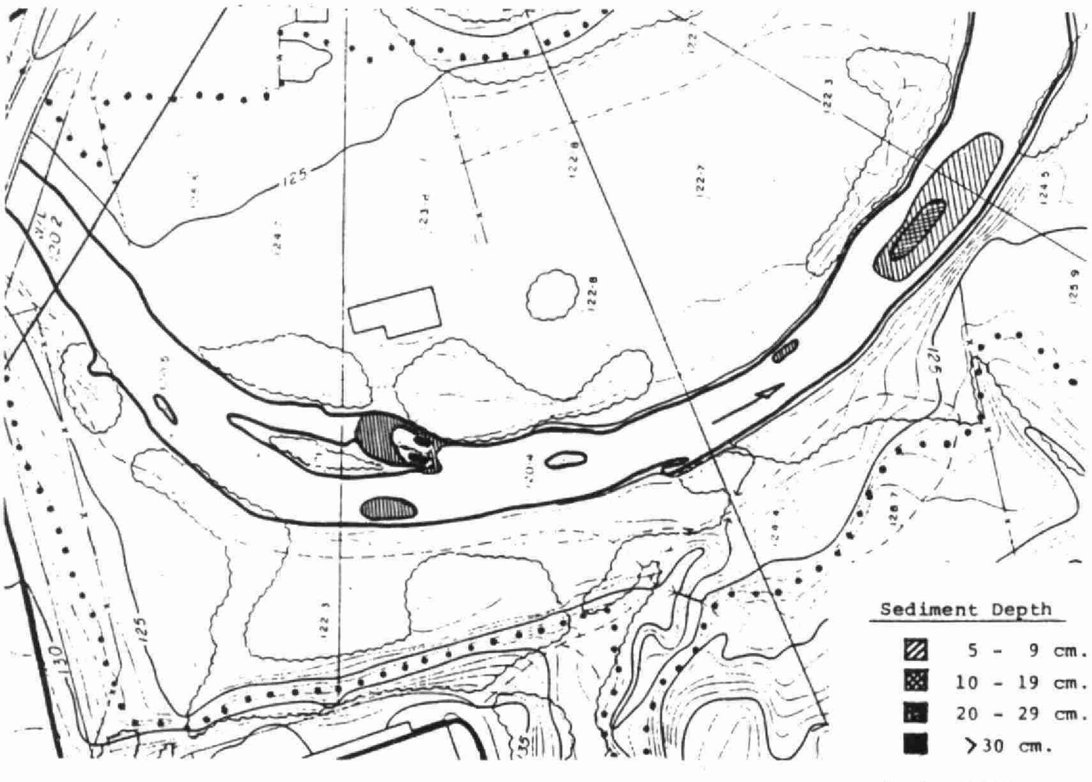

Figure D6 Topographic Map of Sediment Deposition - Zone # 30

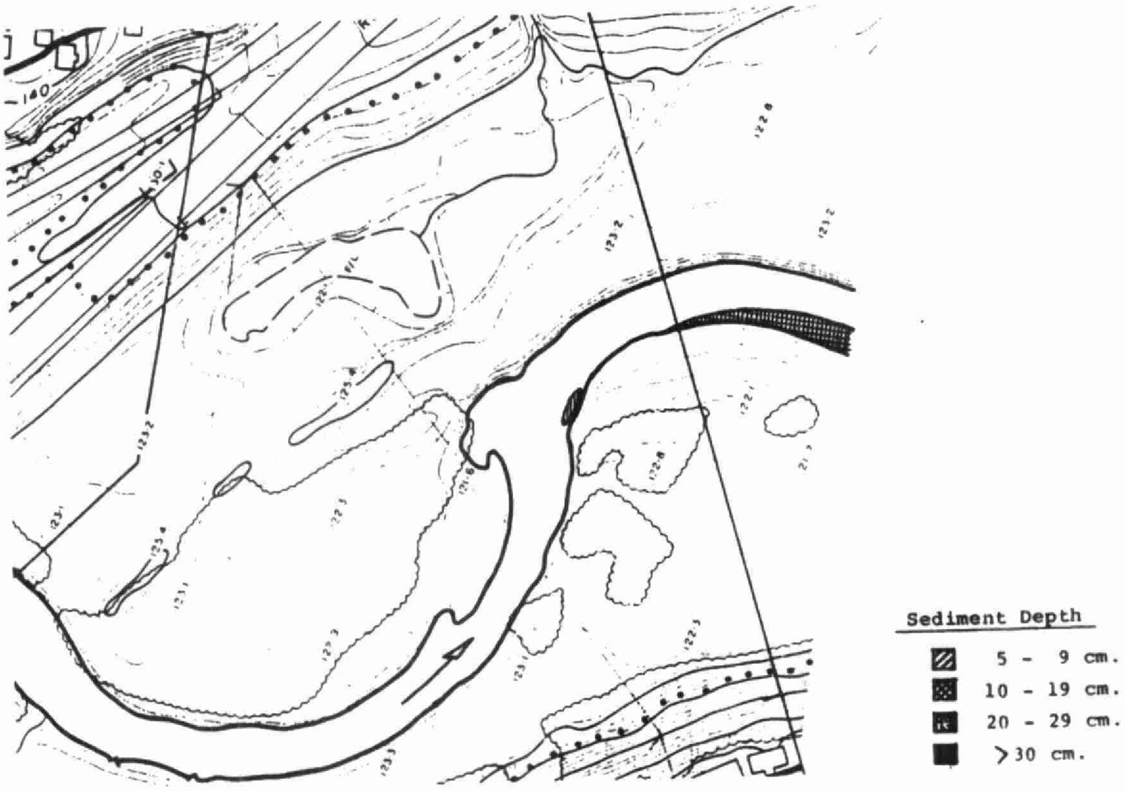

Figure D7 Topographic Map of Sediment Deposition - Zone # 32

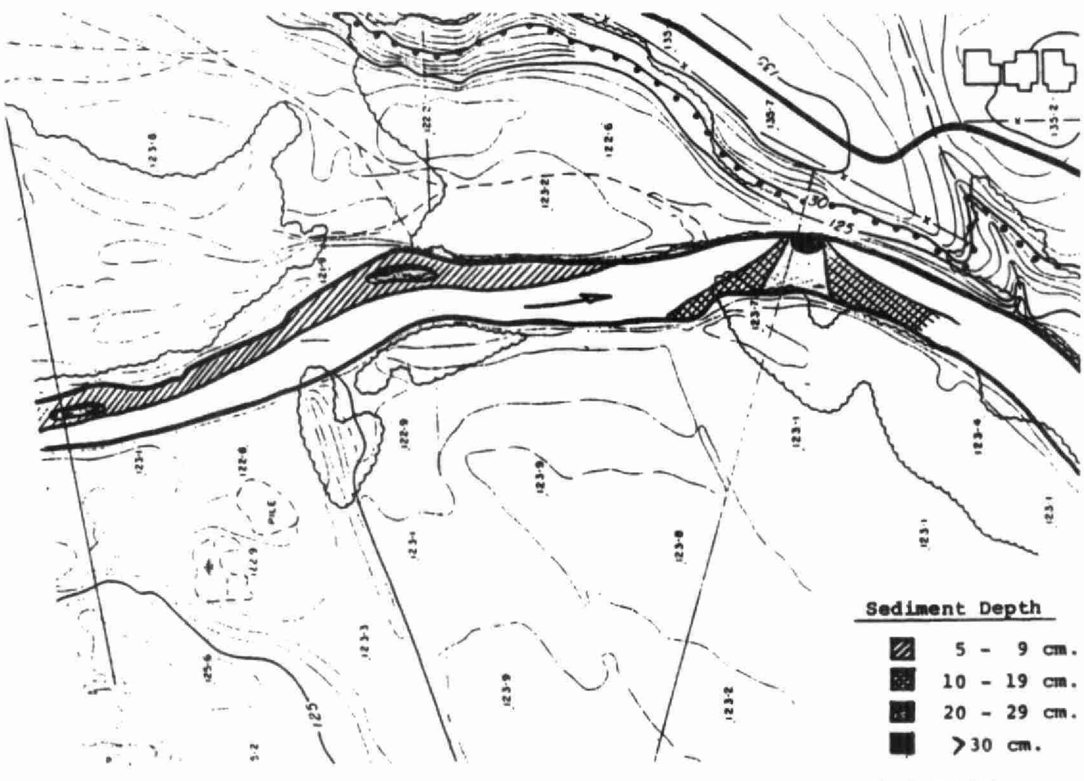

Figure D8 Topographic Map of Sediment Deposition - Zone # 34

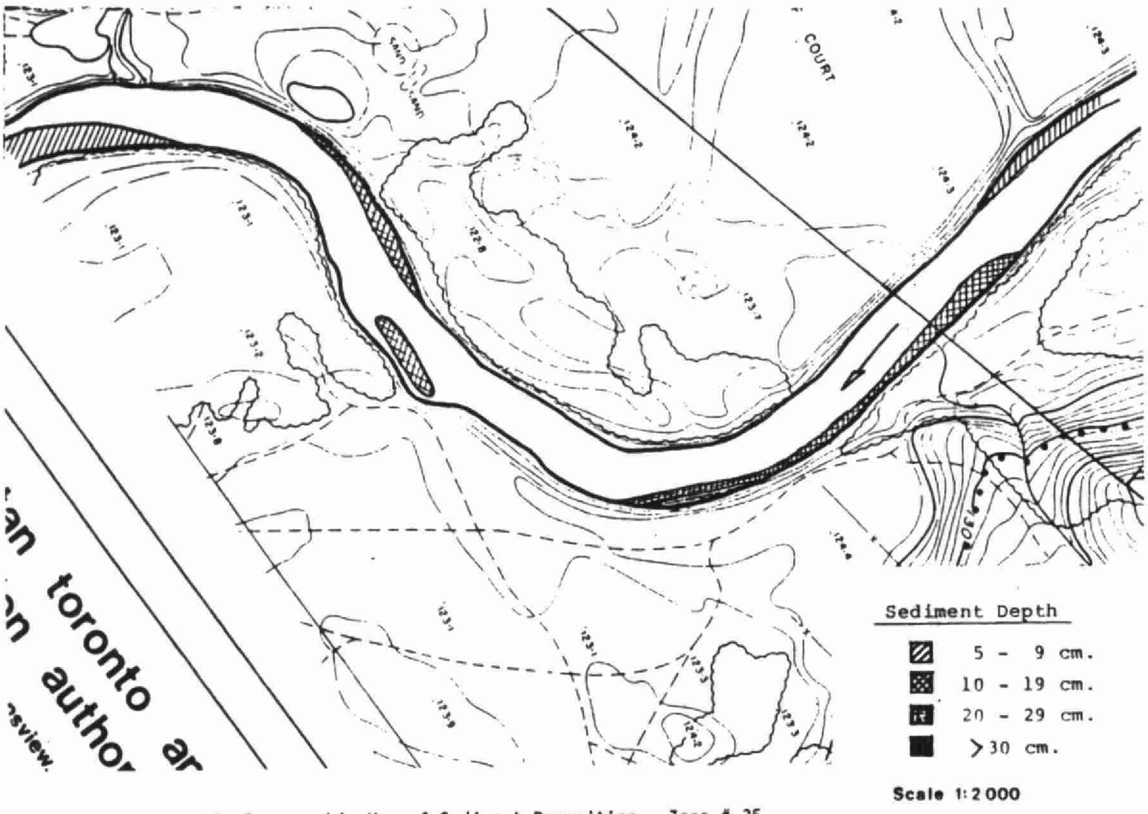

Figure D9 Topographic Map of Sediment Deposition - Zone # 35

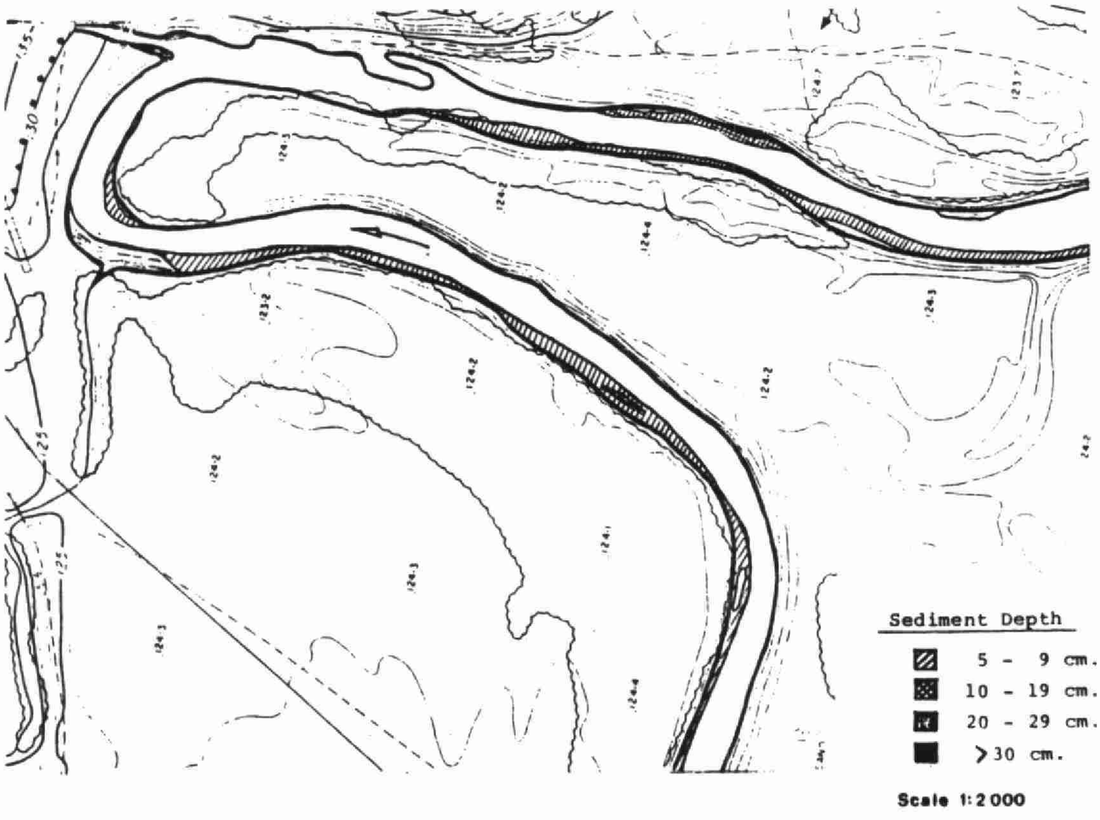

Figure D10 Topographic Map of Sediment Deposition - Zone # 36

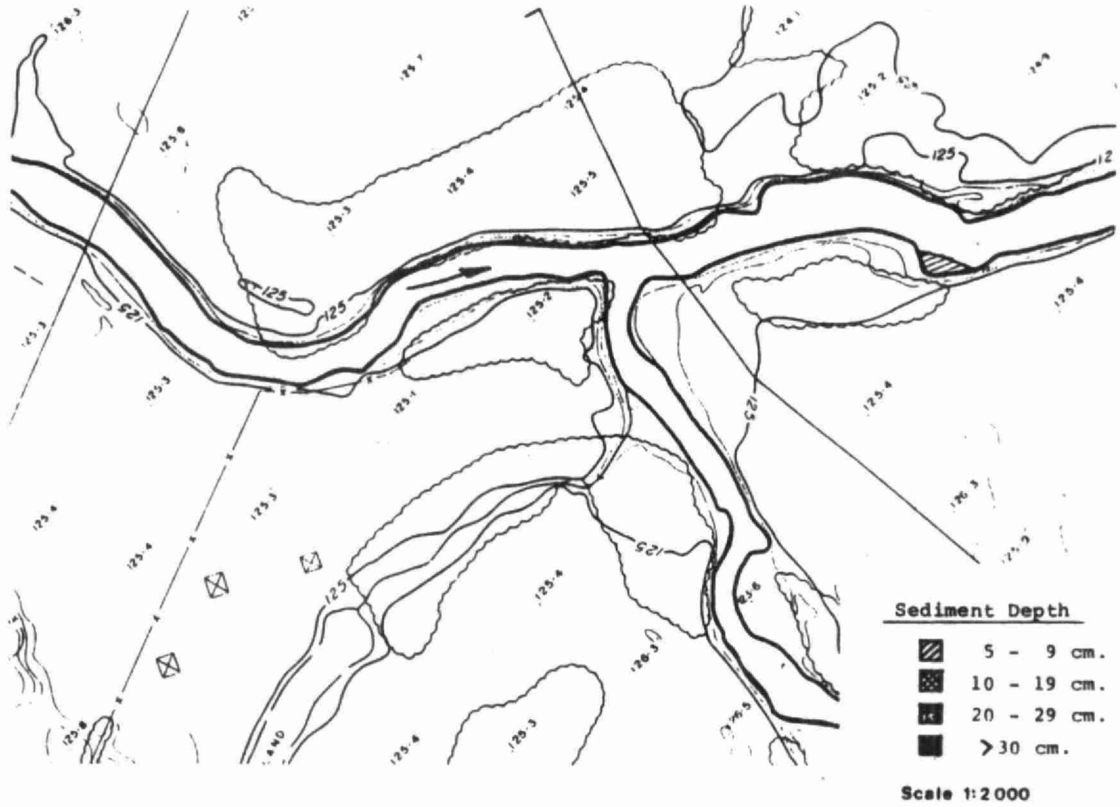

Figure D11 Topographic Map of Sediment Deposition - Zone # 38

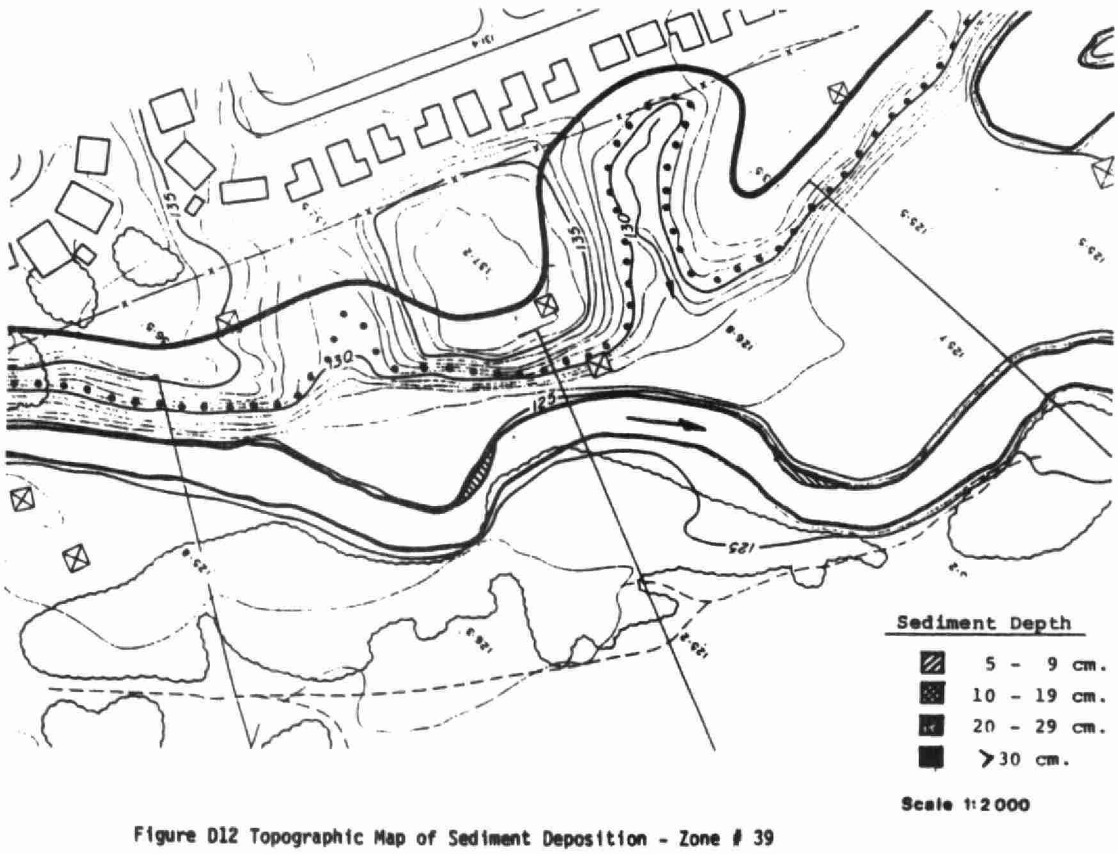

Figure D12 Topographic Map of Sediment Deposition - Zone # 39

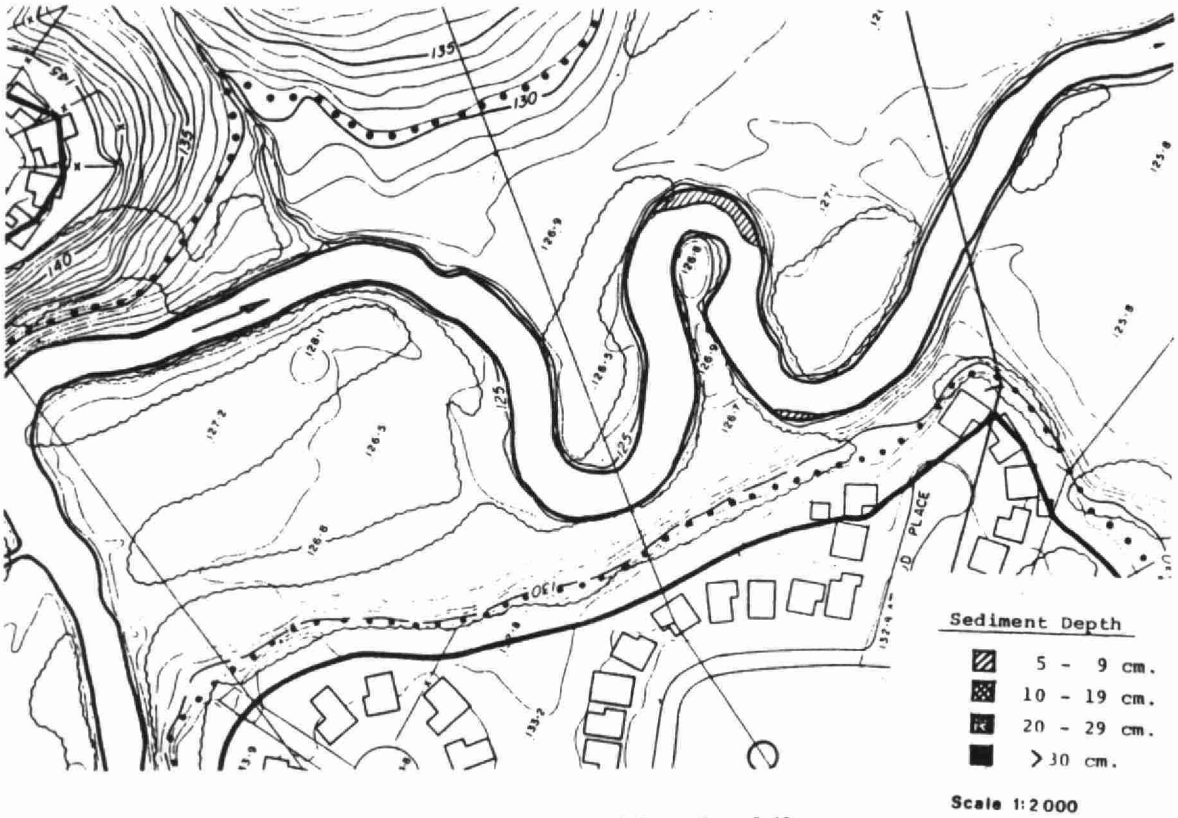

Figure D13 Topographic Map of Sediment Deposition - Zone # 40

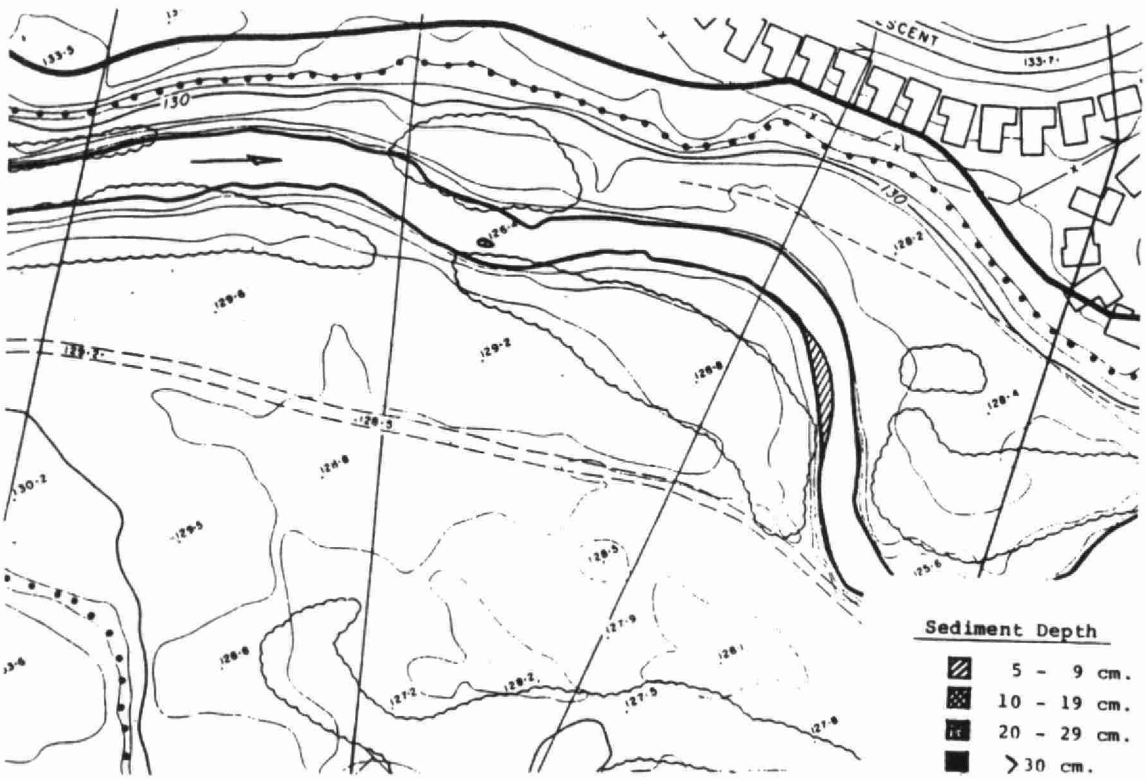

Figure D14 Topographic Map of Sediment Deposition - Zone # 41

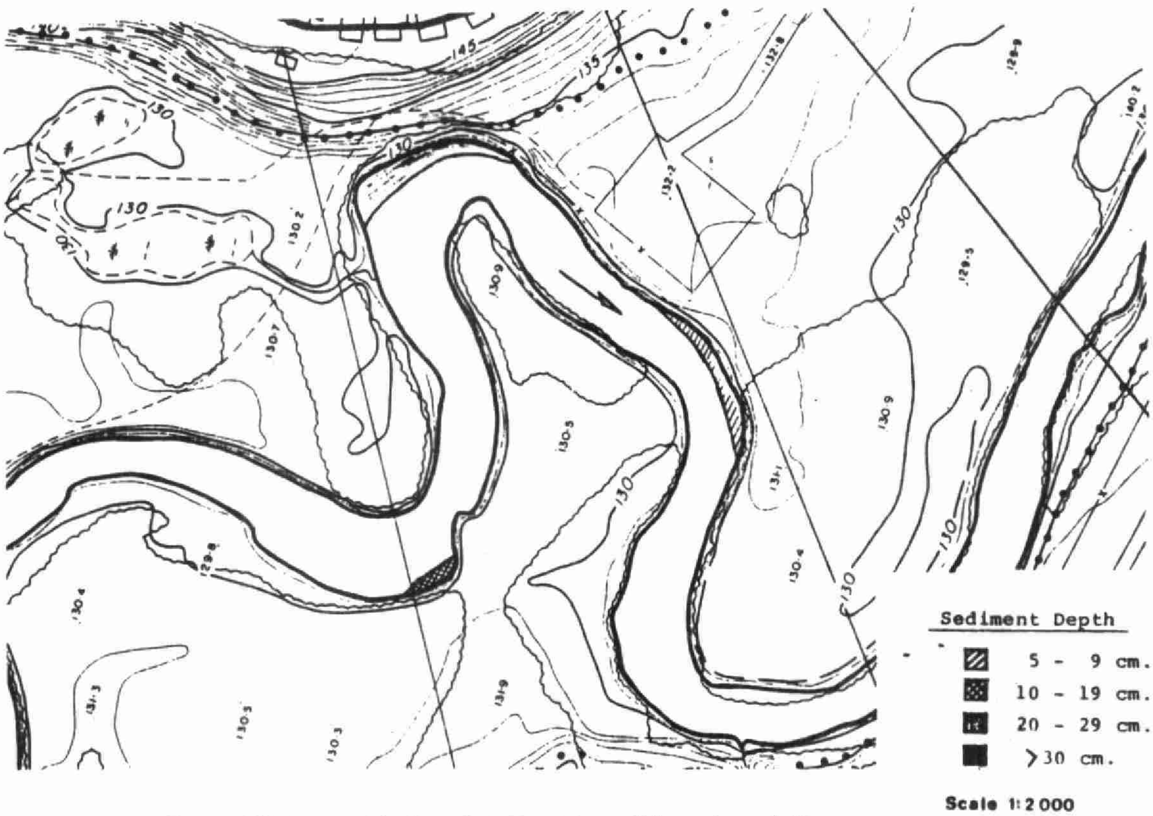

Figure D15 Topographic Map of Sediment Deposition - Zone # 42

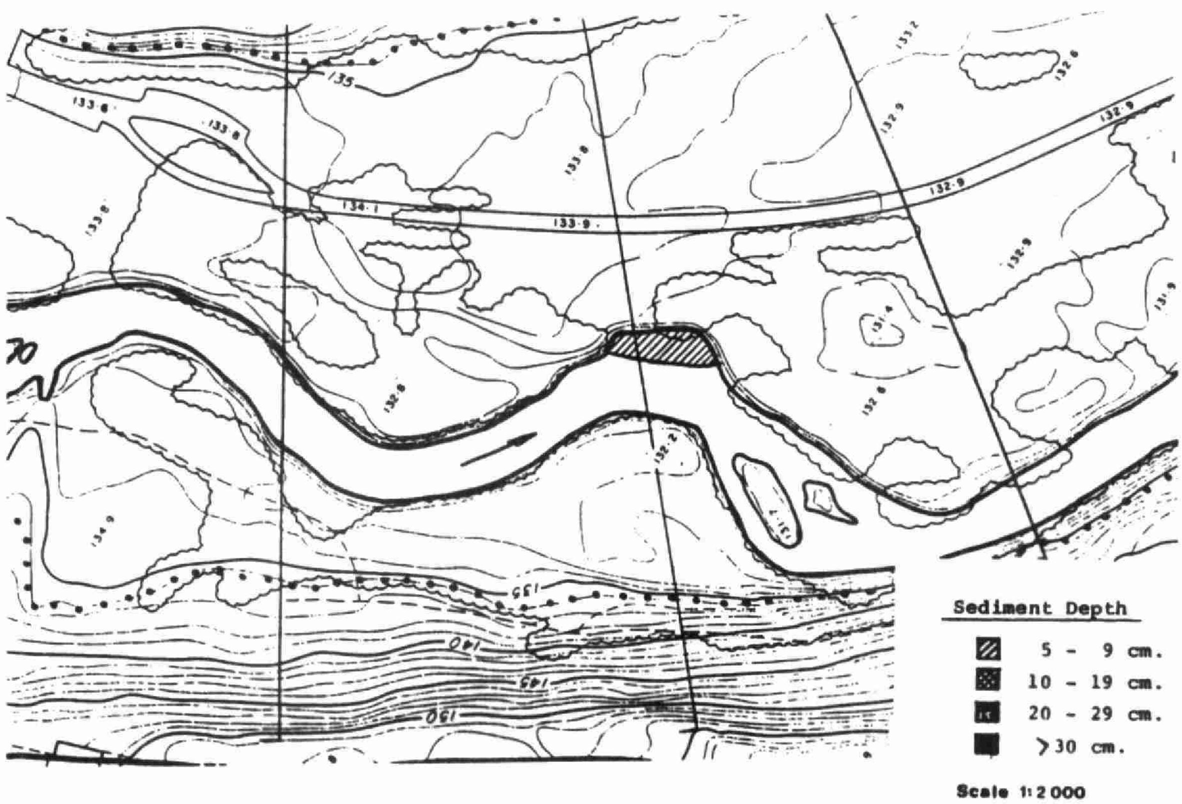

Figure D16 Topographic Map of Sediment Deposition - Zone # 43

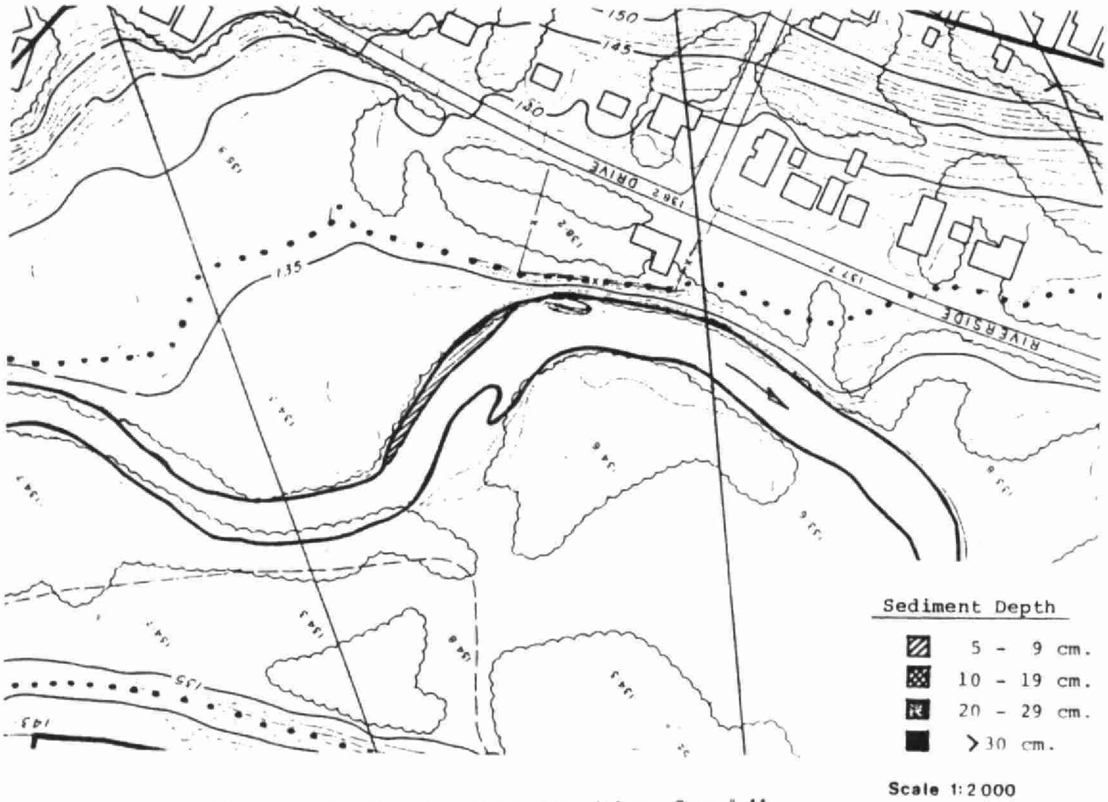

Figure D17 Topographic Map of Sediment Deposition - Zone # 44

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